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AUTHOR Albracht, James; French, Byron
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ABSTRACT

This core curriculum contains five units of material for teaching energy to vocational agriculture students. Energy uses and the benefits of energy conservation are covered in a unit on the impact of energy on agriculture. Discussed next are tractor performance and Nebraska tractor test data for selecting and evaluating tractors for maximum fuel efficiency. Proper ballasting of a tractor as well as operational procedures such as proper matching of tillage equipment to the tractor, gearing up and throttling down, and minimized idling are covered in a unit dealing with tractor operation for maximum fuel efficiency. Addressed next are the following topics: terms related to petrochemical energy use in agriculture, recognizing the amounts of energy these represent, various practices in the use of petrochemicals, and alternatives to their use in farming. Grain production, harvesting, handling, and storage practices that save energy are examined. Included in each unit are a terminal objective; specific objectives; suggested activities; instructional materials (objectives, information sheets, and transparency masters); a unit test; and test answers. (A related core curriculum for teaching metrics to vocational students is available separately--see note.) (MN)

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ED209541

ENERGY AND AGRICULTURE

A Basic Core Curriculum for Teaching Energy to Vocational Agriculture Students.

PREPARED BY:

James Albracht, Project Director
Byron French, Graduate Research Assistant
Adult and Occupational Education
College of Education
Kansas State University
Manhattan, Kansas 66506

FUNDED BY:

Dean Prochaska, Director
Vocational Division
Kansas State Department of Education
Topeka, Kansas 66612

CE030652

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ENERGY AND AGRICULTURE

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Unit IV: Petrochemical Agriculture

Unit V: Grain Production, Harvesting, Handling and Storage Practices that Save Energy

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ENERGY AND AGRICULTURE

UNIT I

THE IMPACT OF ENERGY ON AGRICULTURE

TERMINAL OBJECTIVE

Upon completion of this unit, students will be able to match terms, list energy uses and the benefits of energy conservation. This objective will be considered achieved by scoring at least eighty-five percent on the test.

SPECIFIC OBJECTIVES

After completion of this unit, students will be able to:

1. Match energy terms with the correct definitions.
2. State the current amount of energy being consumed, the amount of increase for periods 1960 to 1980, 1980 to 2000, and which form of energy useage is increasing the most.
3. Name the three major sources of energy and indicate the percentage of U.S. energy needs that each supplies.
4. List the three main energy using sectors and give the relative percentage of energy used by each. Show how agriculture overlaps all three sectors by giving the percentages of energy use for each agriculture sector use.
5. Indicate the amount of energy used in making fertilizers, herbicides, and insecticides for agriculture.
6. Match percentages of energy used.
7. Match percentages of energy being supplied by various energy sources for on-farm agriculture production.
8. Recognize the major causes of energy problems in the United States.
9. List three possible effects of energy problems on agriculture.
10. State two basic reasons for energy conservation.

ENERGY AND AGRICULTURE

UNIT I

SUGGESTED ACTIVITIES

Instructor:

1. Provide students with Objective Sheet
2. Provide students with Information Sheets
3. Make Transparencies
4. Discuss Terminal and Specific Objectives
5. Discuss Information Sheets
6. Give Test

Students:

1. Read Objectives
2. Study Information Sheets
3. Take Test

INSTRUCTIONAL MATERIALS

Included in this unit:

1. Objectives
2. Information Sheets
3. Transparency Masters

   TM 1 - MEASURING ENERGY

   TM 2 - AMERICA'S ENERGY FOUNDATION ...Three Fossil Fuels

   TM 3 - PRIMARY ENERGY USES

   TM 4 - ENERGY USES IN AGRICULTURE NATIONAL AVERAGE

   TM 5 - ENERGY FOR ON FARM PRODUCTION

   TM 6 - ENERGY SOURCES FOR AGRICULTURE

   TM 7 - ENERGY SUPPLY VS. DEMAND

4. Test
5. Answers to Test

INSTRUCTIONAL MATERIALS

References:

1. Weaver, Kenneth F. "Our Energy Predicament," National Geographic, Special Report, (Feb. 1981).

2. Public Affairs Department, Gulf Oil Corporation. An Eagle Eye On Energy, A Resource-action Booklet For Students In Intermediate Grades. Houston, Texas 77001, Gulf Oil Corporation, 1977, Teachers Library, Inc.

3. U.S. Department of Energy. Citizen's Workshops On Energy And The Environment Handbook. Washington, D.C. 20585, U.S. Department of Energy, Office of Public Affairs (Communications Services), 3-78.

ENERGY AND AGRICULTURE

UNIT I

INFORMATION SHEET

I. Terms and Definitions

A. B.T.U. - British Thermal Unit, amount of heat required to raise one pound of water one degree fahrenheit

B. Energy conservation - Any practice that reduces the amount of energy necessary to accomplish a task

C. Fossil fuels - Fuels formed from decomposed remains of plants and animals exsisting millions of years ago, examples are coal crude oil, and natural gas

D. Quad - A quadrillion B.T.U.'s, a unit of measure for an extremely large amount of heat energy

II. Overview of Energy Consumption (TM 1)

A. The amount of total energy a nation uses is measured in Quads, and the U.S. will use 80 quads of energy in the year 1981.

B. In 1980 the U.S. used twice as much energy than in 1960 and by the year 2000 the U.S. will use again twice as much as that of 1980. (Has been doubling every 20 years currently)

C. Electrical energy consumption is increasing faster than any other energy form at 7% per year.

III. Sources of Energy for U.S. (TM 2)

A. Today 90% of all U.S. energy is supplied by fossil fuels

1. Oil supplies 47%

2. Natural gas supplies 27%

3. Coal supplies 18%

B. Remaining 10% of U.S. energy is supplied by:

1. Hydroelectric power 4%

2. Nuclear power 3%

3. Solar, wind, wood, geothermal, and others 3%

INFORMATION SHEET

IV. U.S. Energy Demand by Consuming Sector (TM 3)

A. Industry uses 36% of the total energy consumed in U.S. Examples are steel manufacturing, automobiles, appliances, trucks, office equipment, industrial parts and machinery. Also included are agricultural oriented industries, such as wood harvesting and lumber mills, tractor, farm machinery, farm hardware, equipment manufacturing, food processing, and canning factories.

B. Household and commercial establishments use 32% of the total U.S. energy consumed. Examples are homes, apartments, hospitals, resteraunts, super markets, offices, schools, and government buildings. Also included are farm homes, farm markets, livestock sale centers, grain trade centers, grain and produce storage facilities, U.S.D.A. offices, farm machinery, and farm supply sales.

C. Transportation uses 32% of total U.S. energy consumption (99% from oil). Private automobiles use 19% of total U.S. energy. Commercial and freight travel use the remaining 13%. Examples of Agricultural Transportation are: cattle, farm grain, and agriculture produce farm trucks, cars for farm business, and distribution of farm equipment and supplies in the U.S., and foreign shipments of agricultural goods.

D. As a part of the three sectors, agriculture uses 17% of all U.S. energy. Three percent of the 17% is used for farm tilling, planting, harvesting crops, and for raising meat and animal products.

V. Energy Uses for the Production of Fertilizers, Herbicides, and Insecticides (TM 4)

A. Fertilizer requires 90% of the total energy input required to make herbicides, insecticides, and fertilizers and also represents the single largest use of energy in production agriculture.

B. It takes considerable energy to make nitrogen fertilizer (85% of this energy input).

C. The remaining 10% is used to manufacture the insecticides and herbicides.

VI. Energy Used for Agricultural Production (TM 5)

A. Field operations - 30%
Transportation - 25%
Irrigation - 20%
Dairy, livestock, poultry - 12%
Crop drying - 8%
Misc. (other specialized uses) - 5%

INFORMATION SHEET

VII. The Farm Energy Needs Are Supplied By Several Sources of Fossil Fuels (TM 6)

A. Gasoline and diesal fuel made from oil (48%) provides the largest protion of the energy used on the farm.

B. Natural gas (36%) supplies a large portion of irrigation and grain drying energy requirements. Nitrogen fertilizers use natural gas as a primary ingredient in their manufacture.

C. LP gas (7%) and electricity (7%) provide a smaller portion of farm energy needs, mostly for heating, lighting, electric motors, irrigation and crop drying.

VIII. Causes of Energy Problems in United States (TM 7)

A. Natural gas and crude oil provide 72% of the nation's energy needs while they represent only 7% of our energy reserves.

B. Reserves of oil and natural gas are being consumed faster than new supplies are being found.

C. Domestic natural gas and oil reserves (including Alaskan and offshore reserves) have declined 21.5% and 16.2% respectively between 1970 and 1975, and may be exhausted by 1990.

D. To meet the demand for energy, the United States has become a major importer of foreign oil. This situation makes us vulnerable to foreign concerns such as embargoes and price hikes.

1. The United States oil imports have grown from 4.34 to 8.35 million barrels of oil per day between 1970 and 1976, but in 1980 we decreased our oil imports by nearly 20% due to conservation and the recession. Today we import about 7 million barrels of oil per day.

2. Presently (1980), the United States imports 50% of the total quantity of oil consumed in this country.

IX. Effects of Energy Problems on Agriculture

A. Higher prices for all forms of energy and products produced from energy. For example, higher prices for natural gas will probably result in higher prices for nitrogen fertilizers.

B. Shortages of natural gas can be expected to occur. A scarcity of natural gas will affect irrigation and nitrogen fertilizer production. Deficient supplies of crude oil may also be a severe problem in the future, as half of agriculture's energy comes from oil. This might create farm fuel shortages.

INFORMATION SHEET

C. Electrical loads from irrigation and air conditioning during hot summer afternoons may exceed electrical generation capacity of a utility. Irrigators may be forced to schedule irrigation operation during off peak periods such as during nights and mornings.

X. Reasons for Energy Conservation

A. A reduction of total fuel consumption will lower farmers total fuel bill. If this reduction is achieved by proper energy conservation techniques, one should expect no decrease in crop yields and an increase in net profits.

B. Energy conservation will save precious energy resources until the technology of alternate energy sources is able to begin replacing oil and natural gas. Energy conservation is not a long term answer since our oil, natural gas, and coal supplies are limited. It will only buy us time to allow the technology of other energy sources to develop further.

Measuring Energy

1 Quad = 1,000,000,000,000,000 BTU's
(1 Quadrillion)
or a Millron x a Billion

Equal to 8,000,000,000 [8 Billion] Gallons of Gasoline

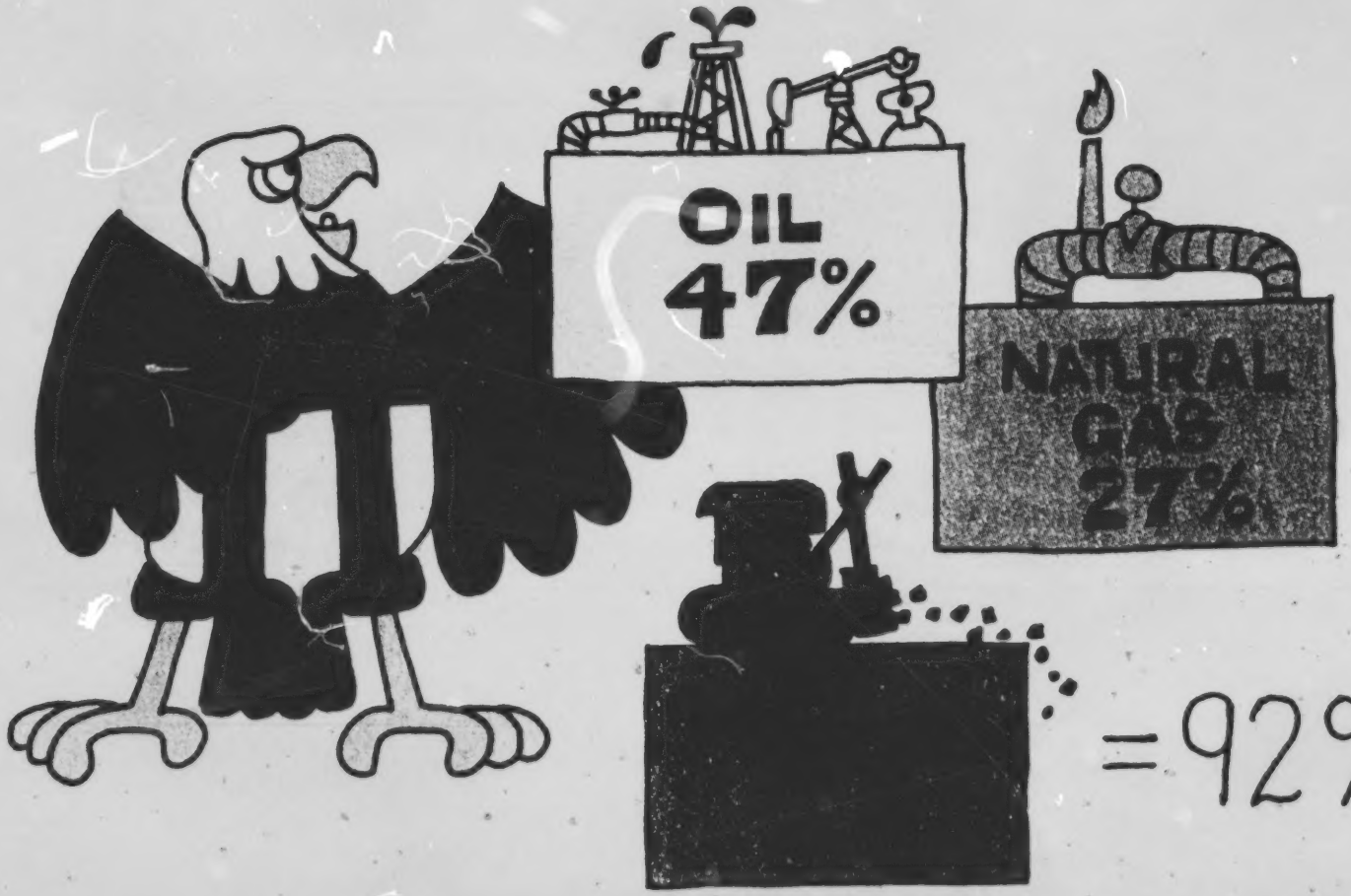
and

a British Thermal Unit or BTU is:

1 BTU = That amount of heat energy required to raise 1 lb of water one degree Farenhieff. (about ¼ of a calorie.)

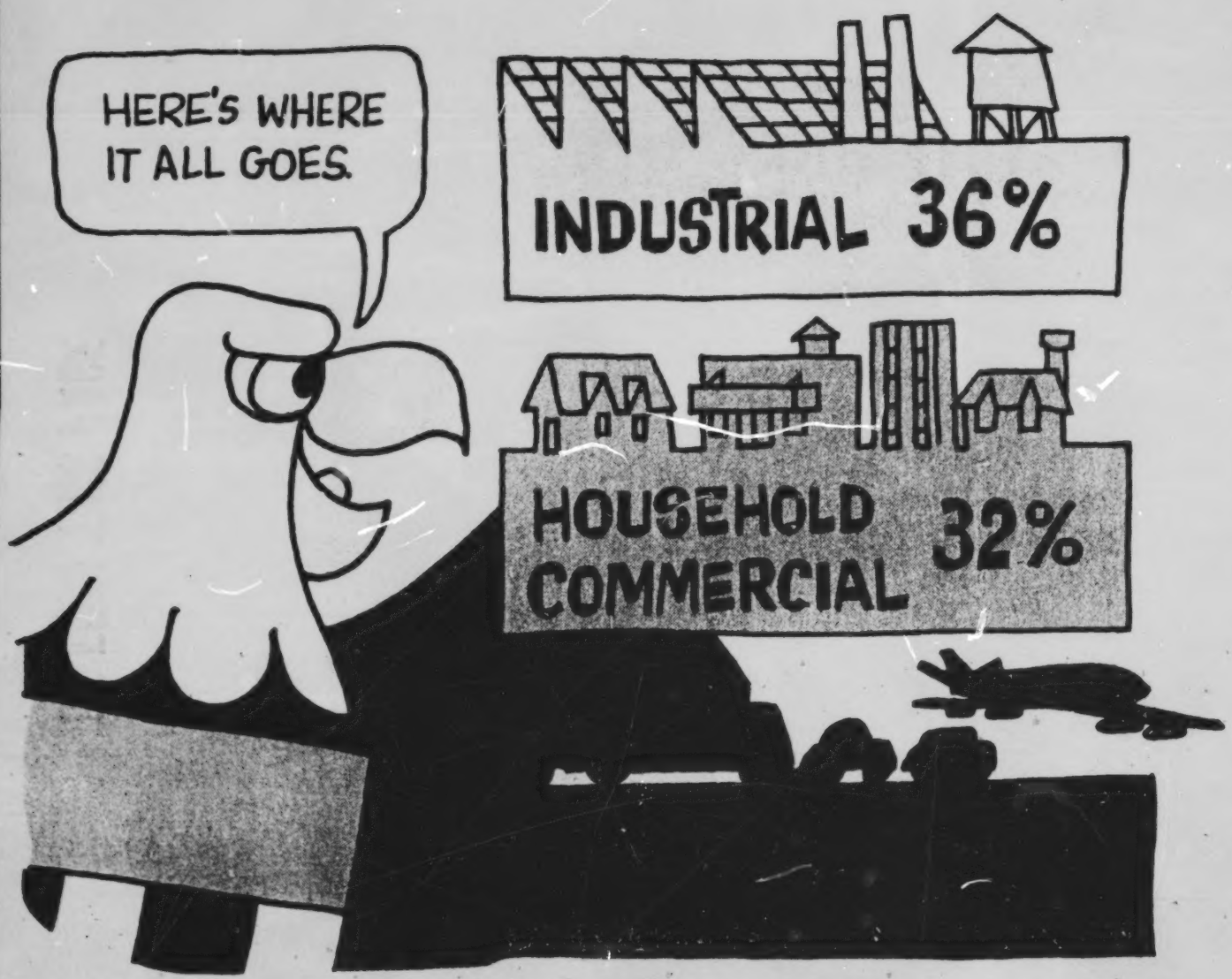
AMERICA'S ENERGY FOUNDATION

...Three Fossil Fuels



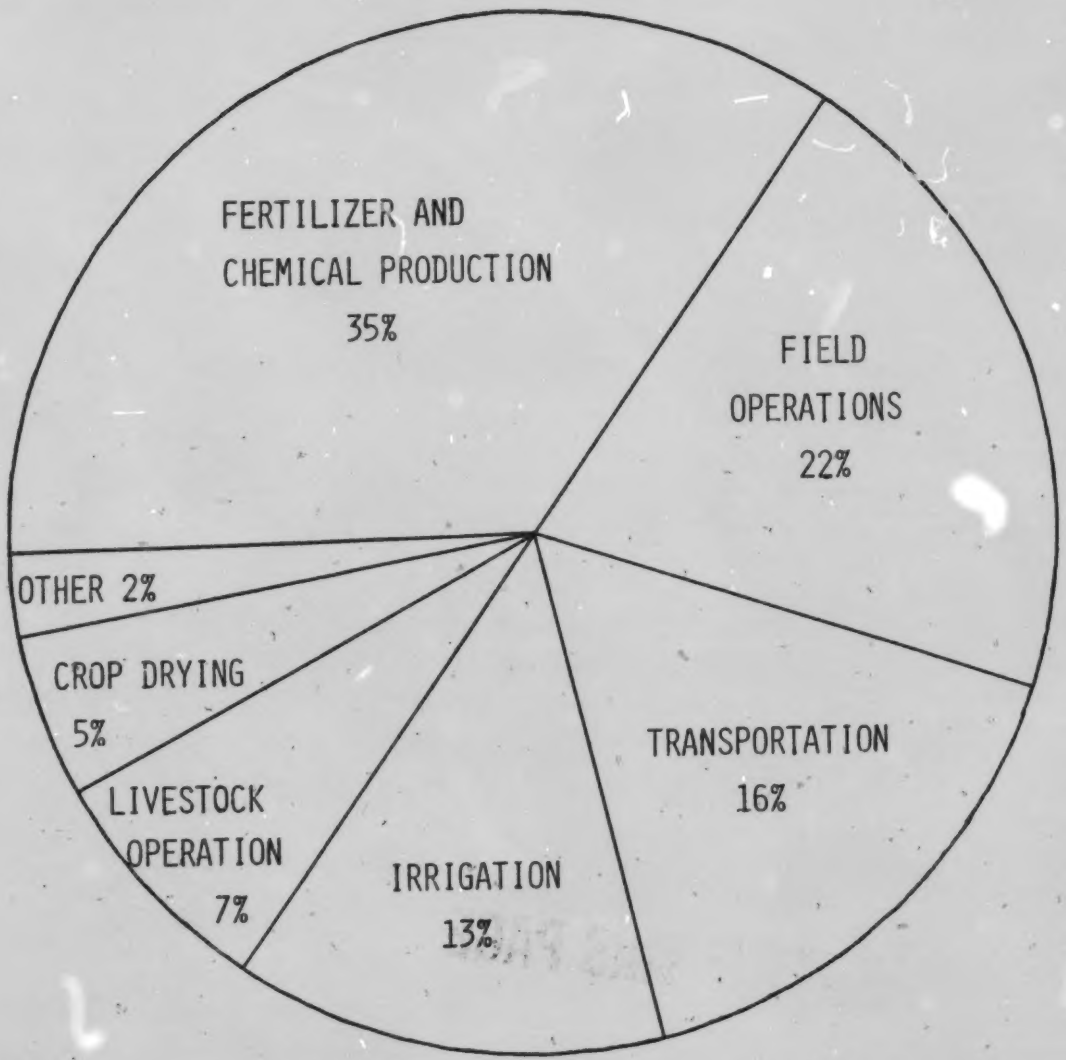
TM 2

SA U1-9

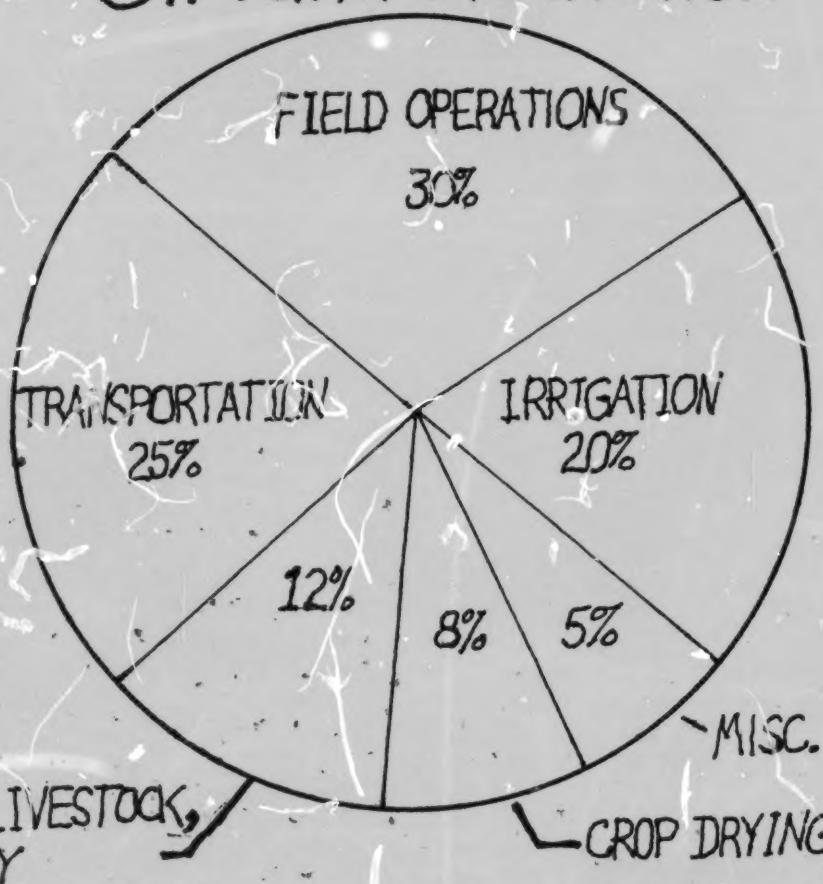

HERE'S WHERE IT ALL GOES.
INDUSTRIAL 36%
HOUSEHOLD COMMERCIAL 32%

ENERGY USES IN AGRICULTURE

NATIONAL AVERAGE

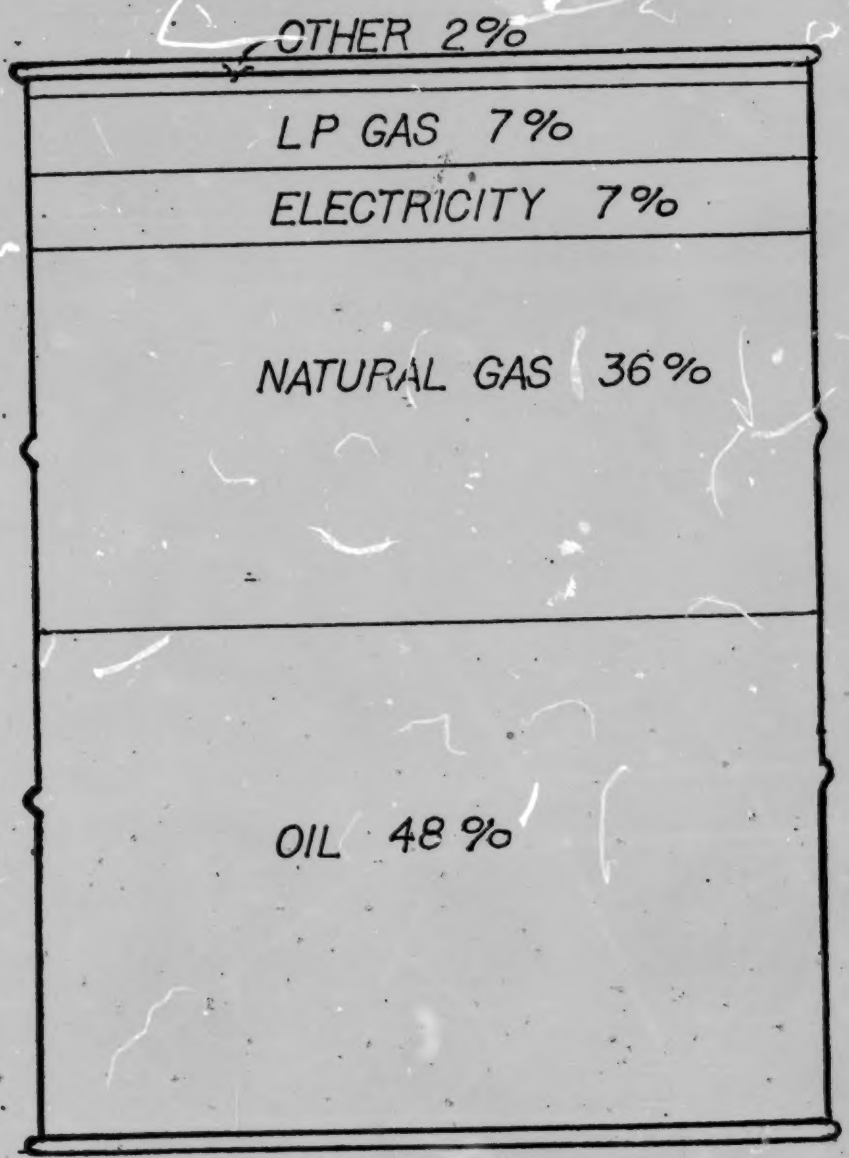


Energy For On Farm Production

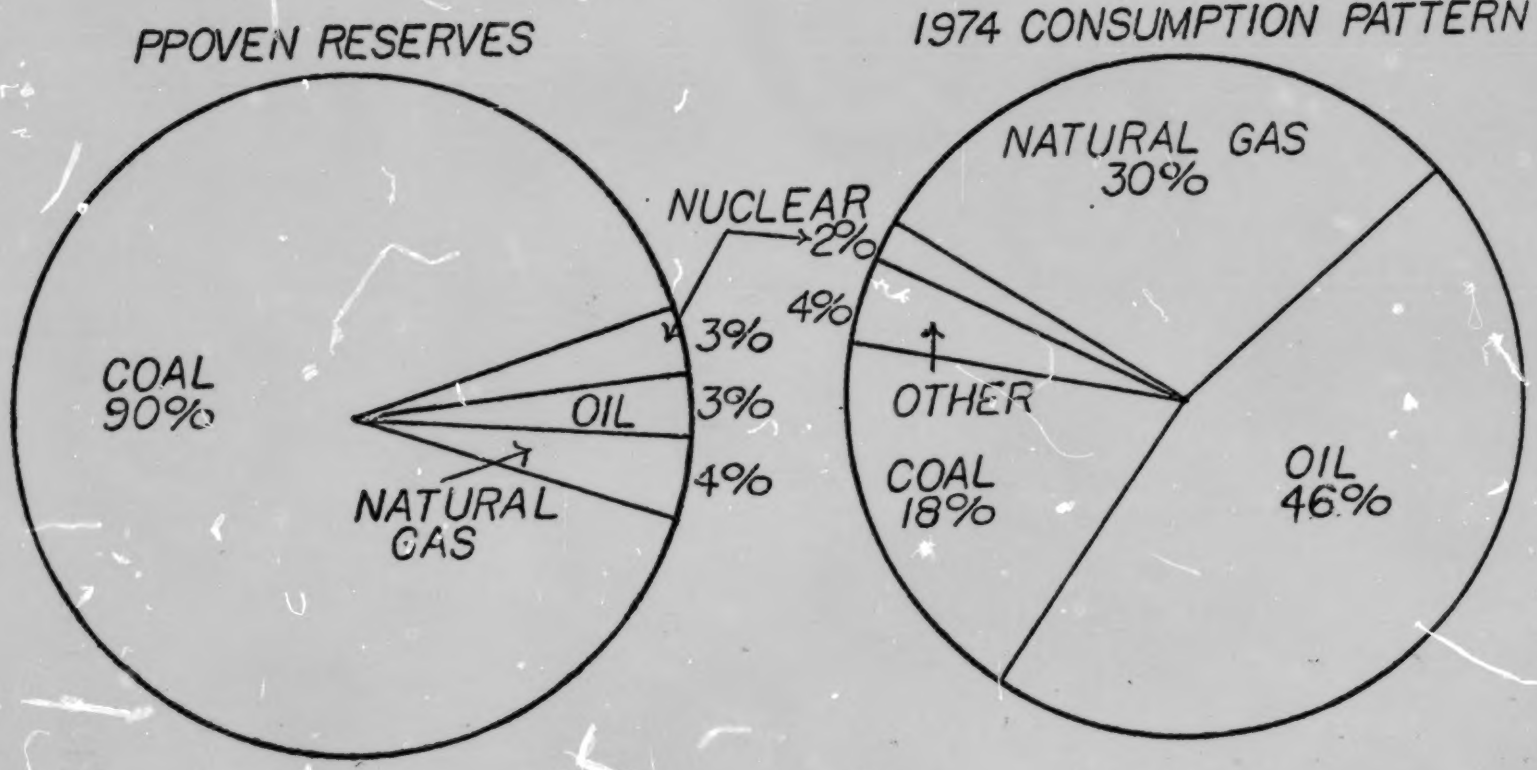


TM5

ENERGY SOURCES FOR AGRICULTURE (1974)



ENERGY SUPPLY VS. DEMAND



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TM 9

ENERGY AND AGRICULTURE

UNIT I

TEST

1. Match the definitions on the right with the correct term in the space provided.

_____a.	B.T.U.	1. Formed from decomposed remains of plants and animals living millions of years ago
_____b.	Quad	2. A million times a billion B.T.U.'s
_____c.	Fossil fuels	3. Any practice that reduces energy consumption
_____d.	Energy conservation	4. The amount of heat required to raise one pound of water one degree fahrenheit

2. State the current amount.

   a. The current amount of energy being consumed in the United States is _____.

   b. The amount of energy consumption increase for periods 1960 to 1980 is _____ and 1980 to 2000 is _____ again.

   c. Which form of energy consumption is most rapidly increasing?
   _____

3. Name the three major sources that supply U.S. energy and indicate the percentage each supplies toward U.S. energy needs.

   a. _____ supplies _____% of U.S. energy

   b. _____ supplies _____% of U.S. energy

   c. _____ supplies _____% of U.S. energy

4. List the three main energy using sectors in the U.S. and give percentage of U.S. total energy consumption for each sector.

   a. _____ uses the most energy at _____%

   b. _____ uses _____% of total U.S. energy

   c. _____ uses _____% of total U.S. energy

   d. As a part of all of the above three sectors, agriculture as a whole is said to use _____% of total U.S. energy of which only _____% is used for actual on farm agriculture production.

TEST

5. Indicate whether the following three statements regarding fertilizers, and insecticides and energy are true or false. (Circle the correct answer)

   a. T F Considerable energy goes into manufacturing fertilizers, herbicides, and insecticides.

   b. T F Of all the energy used in production, herbicides utilize the most energy.

   c. T F It takes about 85% of all the energy used for fertilizers to make nitrogen fertilizer.

6. Match the given percentages of energy used with the correct farming processes.

a.	_____% field operations	12%
b.	_____% transportation	25%
c.	_____% irrigation	8%
d.	_____% dairy, livestock, poultry	30%
e.	_____% crop drying	5%
f.	_____% misc. (other specialized uses)	20%

7. Match percentages of energy being supplied by the following energy sources for farming operations.

a.	_____% gasoline and diesel fuels	7%
b.	_____% natural gas	48%
c.	_____% LP gas and electricity	36%

8. Place an X by the major causes of our energy problems.

_____a. The forms of energy Americans rely on are in short supply.

_____b. The demand for energy has been decreasing steadily the past five years.

_____c. Most of industry is using too much coal and too little crude oil.

_____d. The United States is subject to foreign politics due to our large oil imports.

_____e. Natural gas has become more expensive than other fuels.

TEST

9. List three effects of energy problems on U.S. agriculture.

   a.

   b.

   c.

10. State two basic reasons for energy conservation.

   a.

   b.

ENERGY AND AGRICULTURE

UNIT I

ANSWERS TO TEST

1. a. 4 c. 1
   b. 2 d. 3

2. a. 80 quads
   b. Doubled, doubled
   c. Electrical

3. a. Oil, 47%
   b. Natural gas, 27%
   c. Coal, 18%

4. a. Industry, 36%
   b. Households and commercial establishments, 32%
   c. Transportation, 32%
   d. 17%, 3%

5. a. T
   b. F
   c. T

6. a. 30% d. 12%
   b. 25% e. 8%
   c. 20% f. 5%

7. a. 48%
   b. 36%
   c. 7%

8. The following should have an X:
   a. d.

9. a. Higher prices for our energy and products produced from energy.
   b. Shortages of natural gas for irrigation and fertilizer and crude oil for fuel.
   c. Electrical demands may exceed generating capacity causing irrigation schedule problems.

ANSWERS TO TEST

10. a. Lower fuel bills, increases profits.

    b. Saves energy resources giving U.S. time to develop alternative energy sources.

ENERGY AND AGRICULTURE

UNIT II

TRACTOR PERFORMANCE AND TEST DATA EVALUATION FOR MAXIMUM EFFICIENCY

TERMINAL OBJECTIVE

Upon completion of this unit, students will be able to use the Nebraska tractor test data for selecting and evaluating tractors for maximum fuel efficiency and exhibit knowledge that he understands the important features of this data. This objective will be considered achieved by scoring at least eighty-five percent on the test.

SPECIFIC OBJECTIVES

After completion of this unit, students will be able to:

1. Match terms associated with tractor test data to the correct definitions.
2. Compare the fuel consumption for a diesel, gasoline, and LP-gas tractor.
3. Recognize the major reasons for the difference in fuel economy for a diesel, gasoline, and LP-gas tractor.
4. Name the major types of tests run for Nebraska Tractor Tests.
5. Name the important factors to consider when comparing tractors by use of the Nebraska Tractor Tests.

ENERGY AND AGRICULTURE

UNIT II

SUGGESTED ACTIVITIES

Instructor:

1. Provide students with Objective Sheet
2. Provide students with Information and Assignment Sheets
3. Make Transparencies
4. Discuss Terminal and Specific Objectives
5. Discuss Information and Assignment Sheets
6. Give Test

Students:

1. Read Objectives
2. Study Information Sheets
3. Complete Assignment Sheet and turn in to instructor
4. Take Test

INSTRUCTIONAL MATERIALS

Included in this unit:

1. Objectives
2. Information Sheets
3. Transparency Masters

   TM 1 - CALCULATION OF WORK

   TM 2 - CALCULATION OF POWER

   TM 3 - TYPICAL FARM TRACTOR FUEL EFFICIENCY

   TM 4 - REASONS FOR FUEL EFFICIENCY VARIATIONS OF DIFFERENT ENGINES

   TM 5 - NEBRASKA TRACTOR TEST 1113 - John Deere 4630

   TM 6 - PULL VS. RPM AT FULL LOAD

INSTRUCTIONAL MATERIALS

4. Assignment Sheet

   #1 - Nebraska Tractor Tests

5. Answer to Assignment Sheet

6. Test

7. Answers to Test

References:

1. "Implement and Tractor Redbook," Source for Nebraska Tractor Tests.

2. Schrock, Mark and Stanley J. Clark, "Getting the Most from your Tractor," Kansas State University Extension Publication FM-14, January, 1976.

3. Schrock, Mark. "Tractor Test Data," Kansas State University Extension Publication MF-418, September, 1976.

ENERGY AND AGRICULTURE

UNIT II

INFORMATION SHEET

I. Terms and Definitions (TM 1,2)

A. Draft - Horizontal force exerted by a tillage implement measured in pounds

B. Work - A force acting through a displayed distance measured in foot-pounds or horsepower-hours (1 HP-HR = 1,980,000 Ft-LBS)
Work = Force X Distance

C. Power - The rate of doing work, normally measured in horsepower

$$\text{Power} = \frac{\text{Force X Distance}}{\text{Time}} \quad \text{or} = \frac{\text{Work}}{\text{Time}}$$

D. Drawbar horsepower - The power required to move a pull-type or mounted implement

$$\text{Drawbar HP} = \frac{\text{Draft (LBS) X Speed (MPH)}}{375}$$

E. PTO horsepower - Power measured at the power take off shaft not including transmission power losses

F. Fuel efficiency - Ratio of generated horsepower to fuel consumption rate (Fuel efficiency measured in horsepower hours per gallon of fuel, the higher the value of HP-HR/GAL the greater the tractor efficiency)

II. Engine Fuels and Efficiencies (TM 3)

A. LP-gas tractor burns 30% more gallons of fuel than a gasoline fueled tractor

B. A gasoline tractor burns 20 to 50% more fuel than a diesel

III. Variations of Efficiency of Fuels (TM 4)

A. Higher compression ratio of engine allows more efficient burning of fuel

Diesel engine compression ratio: 16 to 1
Gasoline engine compression ratio: 8 to 1
LP-gas engine compression ratio: 9 to 1

B. Higher energy content of some fuels provides more energy for doing work

Diesel fuel energy content: 140,000 BTU/GAL
Gasoline energy content: 125,000 BTU/GAL
LP-gas energy content: 96,000 BTU/GAL

INFORMATION SHEET

C. Gasoline and LP-gas engines have to overcome restrictions of throttle, whereas diesel doesn't have a throttle

IV. Information from Nebraska Tractor Tests (TM 5)

A. PTO performance tests provide information on horsepower, fuel consumption and efficiency run at wide open throttle for maximum power and various lower power levels

B. Drawbar performance tests at various power levels, gear ranges, conducted on concrete track

1. Will be 10 to 13% less than PTO due to transmission inefficiencies and ballasting problems

2. Tests indicate lower fuel efficiency due to these losses

C. Varying drawbar pull and travel speed tests a tractors ability to pull through brief overloads without shifting gears

D. Other information provided

1. Noise level under various conditions

2. Tractor weight and tire size

3. Other relevant information on the tractor

V. Factors Involved When Comparing Tractors by Nebraska Tractor Tests (TM 4,6)

A. Fuel efficiency - HP-HR/GAL

1. Best comparison = drawbar performance tests at 50% and 75% of pull at maximum power

2. Tests are comparable to normal field operation of most tractors

3. Average PTO performance test is good indicator of fuel consumption of a tractor in general use

B. Maximum available power

1. Best indication of drawbar horsepower found in test labeled "Maximum Power without Ballast"

2. Provides idea of power from various gears

C. Number and spacing of gears for field operation

1. A large number of evenly spaced gears gives most choices of operating a tractor at a speed and power appropriate for a particular tillage tool

INFORMATION SHEET

2. Allows greater fuel efficiency

3. Information under the Drawbar "Maximum Power With (Without) Ballast" test

D. Pull rise

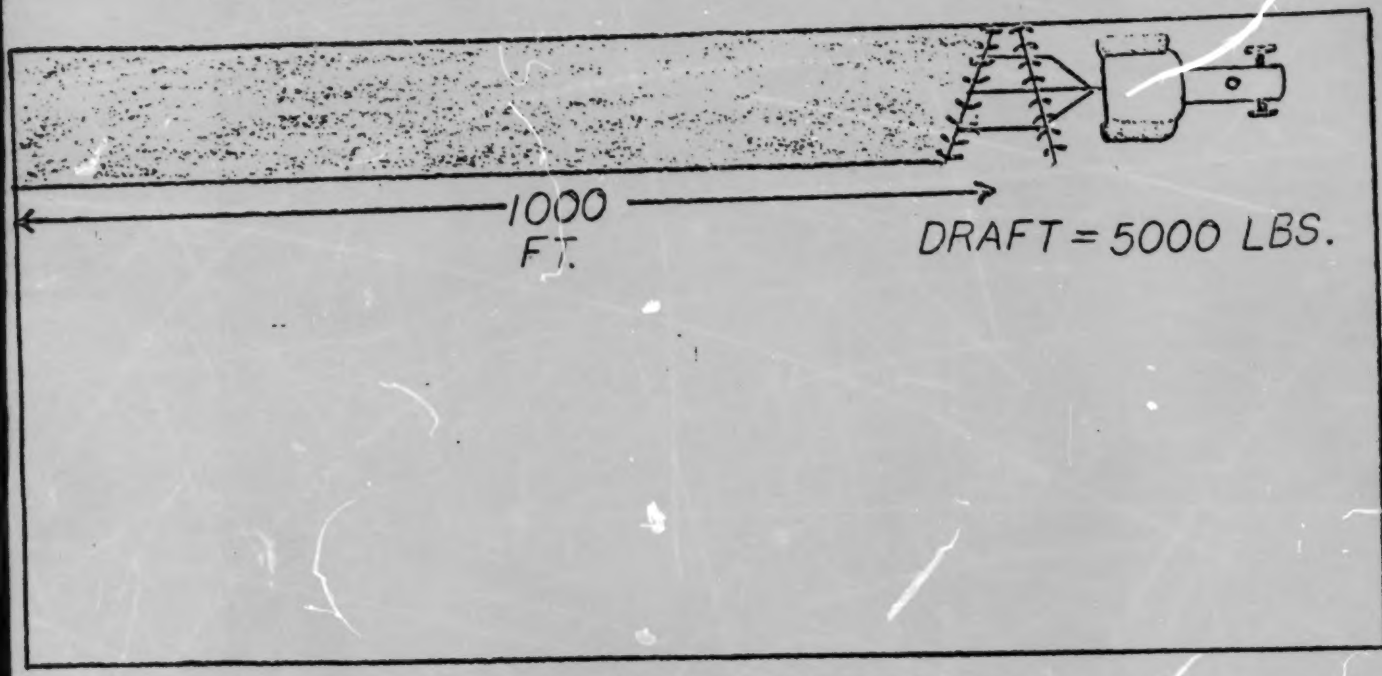
1. Seldom allow a tractor's RPM to drop more than 20% when encountering a tough spot in field operation

2. The rise in pull for the first 20% reduction in RPM is critical

3. Pulling power may level off after this but it should not decrease markedly until a 30% reduction in RPM occurs

E. Caution: Since drawbar tests are run on concrete maximum power and fuel efficiency will drop some under

CALCULATION OF WORK

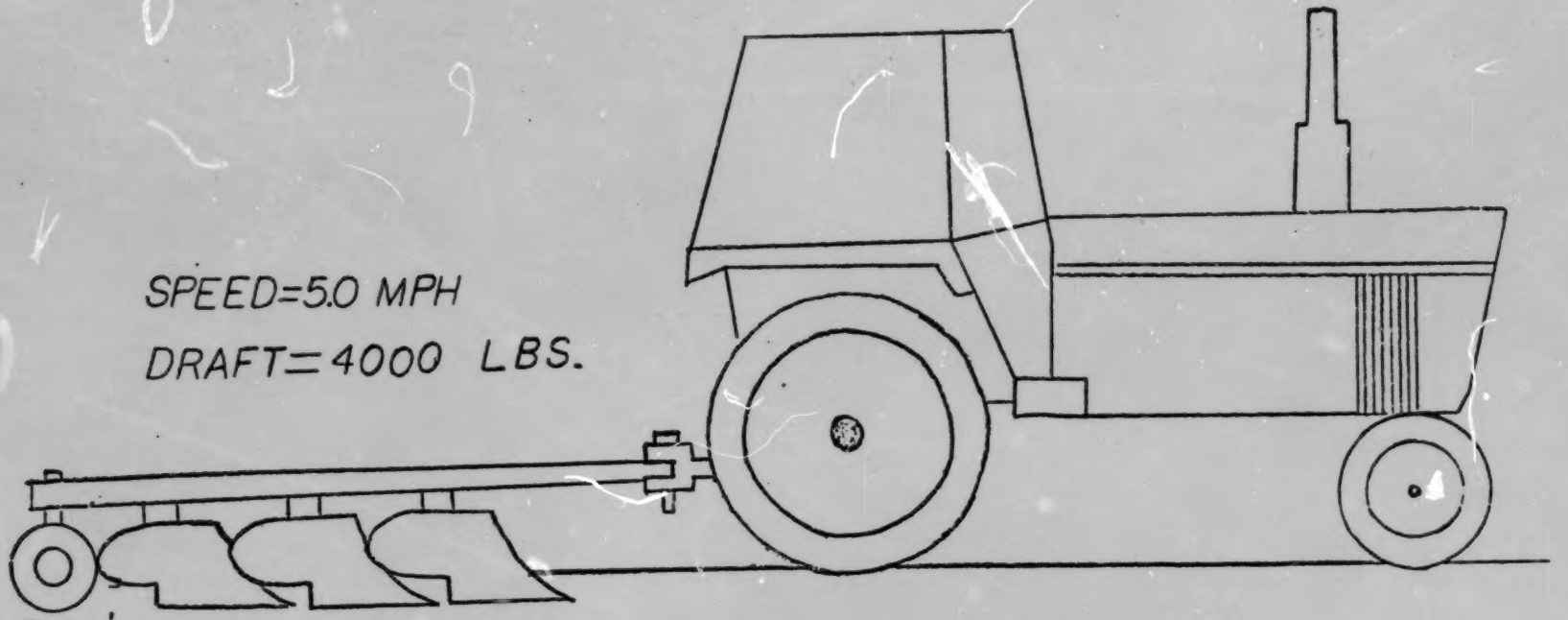


WORK = FORCE x DISTANCE

WORK = 5000 LBS. x 1000 FT. = 5,000,000 FT.-LBS.

$$\text{WORK} = \frac{5000000 \text{ FT.-LBS.}}{1{,}980{,}000 \ \frac{\text{FT.-LBS.}}{\text{HP.-HR.}}} = 2.52 \text{ HP.-HR.}$$

CALCULATION OF POWER



SPEED=5.0 MPH

DRAFT=4000 LBS.

E-28

$$\text{DRAWBAR HP} = \frac{\text{DRAFT (LBS.)} \times \text{SPEED (MPH)}}{375}$$

$$\text{DRAWBAR HP} = \frac{4000 \times 5}{375} = 53.3 \text{ HP}$$

Table 7 Typical Farm Tractor Fuel Efficiency* (Ref. 1)

Load (% of Maximum PTO Horsepower)	PTO Horsepower-Hour/Gallon		
	Gasoline	Diesel	LP-Gas
100	10.2	12.5	7.8
80	9.6	12.4	7.5
60	8.6	11.6	6.6
40	7.1	9.8	5.4
20	4.4	6.5	3.5

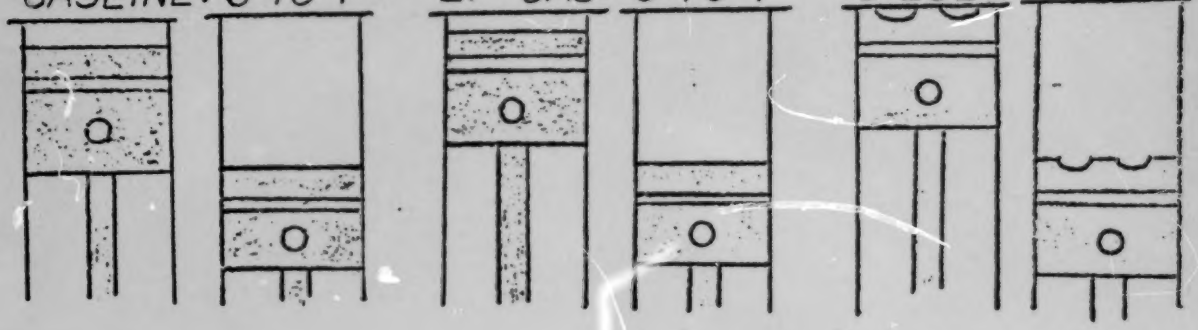
*Averages are from 118 Nebraska Tractor Test with fuel efficiency reduced by 15% to represent typical tractor operation on the farm. Values apply to operation at rated engine speed.

TM3

REASONS FOR EFFICIENCY VARIATIONS OF DIFFERENT FUELED ENGINES

I. DIFFERNT COMPRESSION RATIOS

GASLINE: 8 TO 1 LP GAS: 9 TO 1 DIESEL: 16 TO 1



II. DIFFERENT ENERGY CONTENTS

DIESEL FUEL:	140,000 BTU/GALLON
GASOLINE:	125,000 BTU/GALLON
LP GAS:	96,000 BTU/GALLON

III. THROTTLE PLATE LOSSES AT PART LOAD

NEBRASKA TRACTOR TEST 1113 – JOHN DEERE 4630 POWER SHIFT DIE

Department of Agricultural Engineering

Dates of Test: October 13th to October 21th, 1972

Manufacturer: John Deere Waterloo Tractor Works, Waterloo, Iowa

POWER TAKE-OFF PERFORMANCE

Hp	Crankshaft speed rpm	Fuel Consumption Gal per hr	Fuel Consumption Lb per hp-hr	Hp-hr per gal	Temperature Degrees F Cooling medium	Air wet bulb	Air dry bulb	Barometer inches of Mercury
MAXIMUM POWER AND FUEL CONSUMPTION								
Rated Engine Speed--Two Hours (PTO Speed--995 rpm)								
150.66	2200	9.604	0.443	15.68	186	54	75	29.077
VARYING POWER AND FUEL CONSUMPTION--Two Hours								
132.30	2275	8.915	0.470	14.79	183	54	75	.....
0.00	2389	2.799	.....	.....	170	51	72	.....
67.09	2328	5.811	0.600	11.58	175	53	75	.....
150.55	2200	9.066	0.116	15.53	187	53	76	.....
34.15	2319	4.315	0.881	7.86	169	52	74	.....
100.43	2301	7.411	0.513	13.55	178	53	76	.....
Av 80.85	2307	6.502	0.559	12.43	177	53	75	29.077

DRAWBAR PERFORMANCE

Hp	Drawbar pull lbs	Speed miles per hr	Crankshaft speed rpm	Fuel Consumption Slip of drivers %	Gal per hr	Lb per hp-hr	Hp-hr per gal	Temp Degrees F Cooling med	Air wet bulb	Air dry bulb	Barometer inches of Mercury
VARYING DRAWBAR POWER AND FUEL CONSUMPTION WITHOUT BALLAST											
Maximum Available Power--Two Hours--4th Gear											
127.92	10751	4.46	2200	7.63	9.591	0.520	13.34	180	61	62	28.775
75% of Pull at Maximum Power--Ten Hours--4th Gear											
102.88	8047	5.29	2317	5.77	8.378	0.565	12.86	172	44	44	28.947
50% of Pull at Maximum Power--Two Hours--4th Gear											
70.53	5318	4.97	2312	3.31	6.658	0.655	10.59	169	52	54	28.810
50% of Pull at Reduced Engine Speed--Two Hours--5th Gear											
70.09	5318	4.91	1784	3.28	5.362	0.534	13.05	176	53	54	28.800
MAXIMUM POWER WITHOUT BALLAST											
121.91	11378	3.16	2189	14.53	3rd	Gear.....		180	60	60	28.780
132.02	11105	4.46	2200	7.91	4th	Gear.....		180	55	55	28.780
131.65	8266	5.97	2198	4.85	5th	Gear.....		189	54	55	28.800
131.09	6242	7.88	2199	3.62	6th	Gear.....		190	54	55	28.810
131.56	4920	10.26	2196	2.84	7th	Gear.....		189	55	57	28.810

VARYING DRAWBAR PULL AND TRAVEL SPEED WITHOUT BALLAST with Gear

Pounds Pull	11105	11940	13121	13687	13242	11030
Horsepower	132.02	126.42	120.05	110.02	90.91	67.37
Crankshaft Speed rpm	2200	1981	1762	1519	1317	1126
Miles Per Hour	4.46	3.97	3.43	3.01	2.57	2.28
Slip of Drivers %	7.91	8.75	11.18	11.44	11.18	7.91

TRACTOR SOUND LEVEL (with Sound-Gard cab)	dB(A)
Maximum Available Power 2 Hours	82.5
75% of Pull a Max. Power 10 Hours	83.0
50% of Pull at Max. Power 2 Hours	83.0
50% of Pull at Reduced Engine Speed 2 Hours	82.0
Bystander--8th Gear	89.5

TIRES, BALLAST AND WEIGHT		Without Ballast
Rear tires	--No., size, ply & psi	Four 18.4-38; 8; 16
Ballast	--Liquid	None
	Cast Iron	None
Front tires	No., size, ply & psi	Two 10.00-16; 6; 28
Ballast	--Liquid	None
	Cast Iron	None
Height of drawbar		24 inches
Static weight with operator--rear		12290 lb
front		3960 lb
total		16250 lb

FUEL, OIL AND TIME Fuel No 2 Diesel Cetane No 51.5 (rating taken from oil company's typical inspection data) Specific gravity converted to 60°/60° 0.8312 Weight per gallon 6.916 lb Oil SAE 30 API service classification John Deere Torq Gard or CD-SD To motor 3.681 gal Drained from motor 3.317 gal Transmission and final drive lubricant John Deere Special 303 oil Total time engine was operated 47 hours

ENGINE Make John Deere Diesel Type 6 cylinder with turbo-charger and intercooler Serial No 6101AR-10 511419R Crankshaft Mounted lengthwise Rated rpm 2200 Bore and stroke 4.25" x 4.75" Compression ratio 16.0 to 1 Displacement 404 cu. in. Cranking system electrical (two 6 volt batteries) Lubrication pressure Air cleaner precleaner and two dry type in series with replaceable treated paper elements Oil filter full flow with replaceable paper cartridge Oil Cooler engine coolant heat exchanger for crankcase oil and radiator for transmission and hydraulic system Fuel filter sediment bowl with screen and replaceable paper primary and secondary filter elements Muffler was used Cooling medium temperature control thermostat

CHASSIS Type standard Serial No 4630? 001850R Tread width rear 63.0" to 103.6" front 56.0" to 80.0" Wheel base 112.7" Center of gravity (without operator or ballast, with minimum tread, with fuel tank filled and tractor serviced for operation) Horizontal distance forward from center-line of rear wheels Vertical distance above roadway 42.8" Horizontal distance from center of rear wheel tread 0.7" to the left Hydraulic control system direct engine drive Transmission selective gear fixed ratio with operator controlled full range power shifting Advertised speeds mph first 1.7 second 2.4 third 3.7 fourth 4.8 fifth 6.2 sixth 8.1 seventh 10.5 eighth 17.7 reverse 2.0, 2.9, 4.5, and 5.9 Clutch wet multiple discs operated hydraulically Brakes wet disc hydraulically power actuated by two foot pedals that can be locked together Steering hydrostatic Turning radius (on concrete surface with brake applied) right 155" left 155" (on concrete surface without brake) right 174" left 174" Turning space diameter (on concrete surface with brake applied) right 310" left 310" (on concrete suface without brake) right 318" left 318" Power take-off 1002 rpm at 2200 engine rpm.

REPAIRS AND ADJUSTMENTS: No repairs or adjustments

REMARKS: All test results were determined from observed data obtained in accordance with SAE and ASAE test code or official Nebraska test procedure. First and second gears were not run as it was necessary to limit the pull in third gear to avoid excessive wheel slippage. Eighth gear was not run as test procedure requires only one gear over eight miles per hour.

We, the undersigned, certify that this is a true and correct report of official Tractor Test 1113.

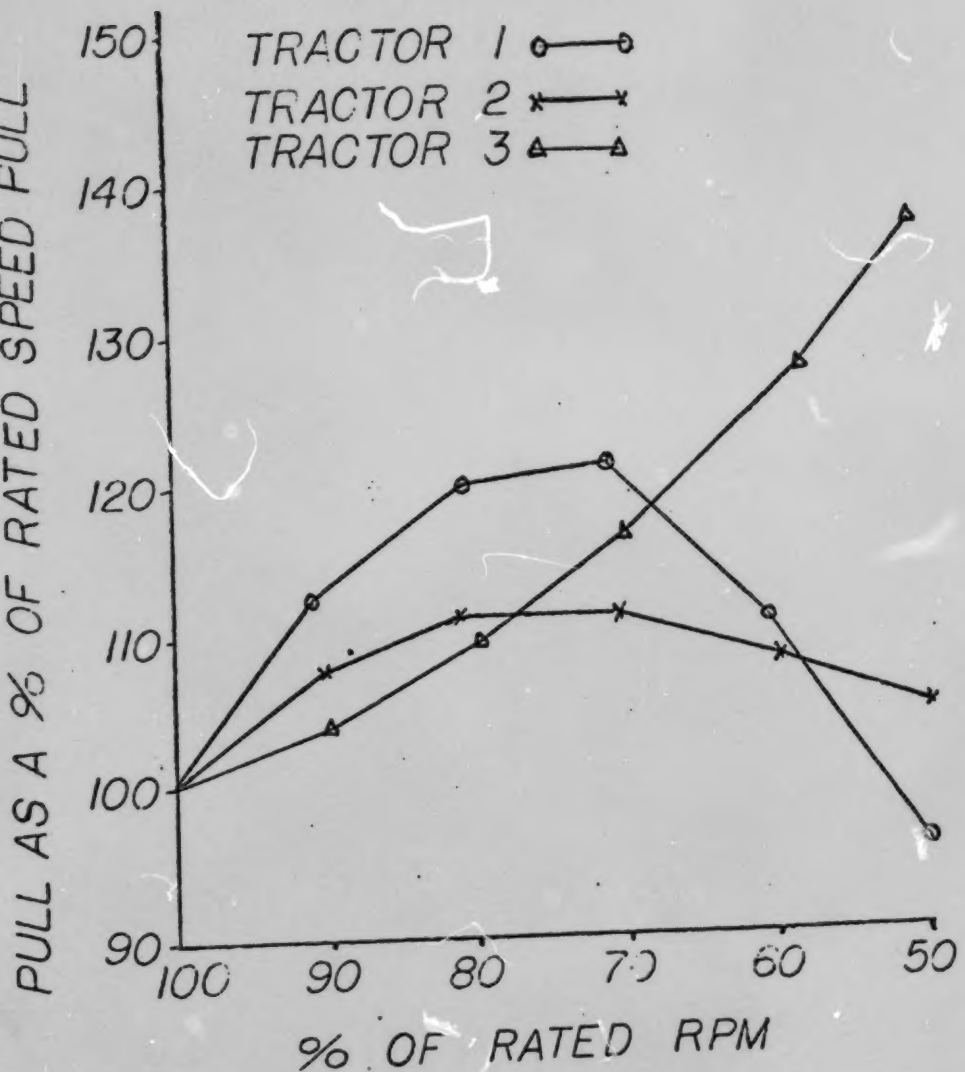
L. F. LARSEN
Engineer-in-Charge

G. W. STEINBRUGGE, Chairman
W. E. SPLINTER
D. E. LANE
Board of Tractor Test Engineers

The University of Nebraska Agricultural Experiment Station
E. F. Frolik, Dean; H. W. Ottoson, Director; Lincoln, Nebraska

TM 5

PULL VS RPM AT FULL LOAD



TRACTOR OPERATION FOR MAXIMUM
FUEL EFFICIENCY
UNIT II

Assignment Sheet #1: Nebraska Tractor Tests

Note: If Nebraska Tractor Tests are not available, they may be obtained from local dealers or those provided may be used.

1. Choose three tractors of approximately the same PTO horsepower and of different manufacturers.

   Tractor 1:

   Tractor 2:

   Tractor 3:

2. List fuel efficiency for each of the three tractors for the 50% and 75% of Pull of Maximum Drawbar Power and the average fuel efficiency of the PTO Varying Power Tests.
   Tractor 1:

   Tractor 2:

   Tractor 3:

3. List the number of gears and their corresponding speeds used in normal field operations (4 to 7 MPH). This data is found in the right hand column of information. For those gears found under the test "Maximum Power With Ballast," also list their power and slip levels. Does the slip affect the maximum power generated at these various gears?

	Gear	Speed (MPH)	HP	Slip
Tractor 1				
Tractor 2				
Tractor 3				

ENERGY AND AGRICULTURE

UNIT II

ASSIGNMENT SHEET #1: Nebraska Tractor Tests

Note: If Nebraska Tractor Tests are not available, they may be obtained from local dealers or those provided may be used.

1. Choose three tractors of approximately the same PTO horsepower and of different manufacturers.

   Tractor 1:

   Tractor 2:

   Tractor 3:

2. List fuel efficiency for each of the three tractors for the 50% and 75% of Pull of Maximum Drawbar Power and the average fuel efficiency of the PTO Varying Power Tests.

   Tractor 1:

   Tractor 2:

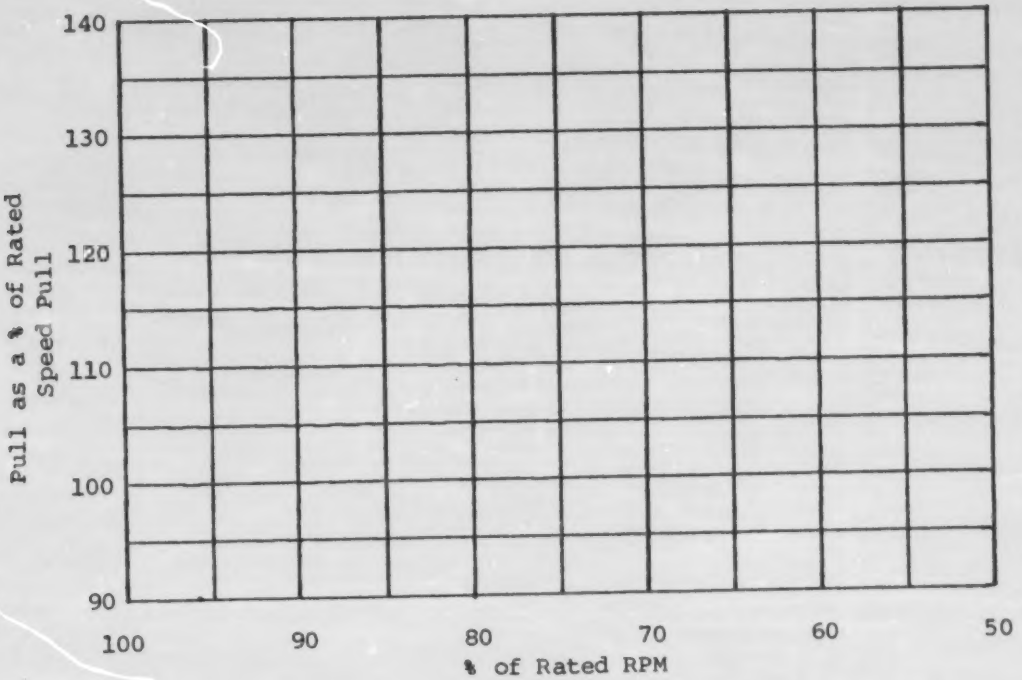
   Tractor 3:

3. List the number of gears and their corresponding speeds used in normal field operations (4 to 7 MPH). This data is found in the right hand column of information. For those gears found under the test "Maximum Power With Ballast," also list their power and slip levels. Does the slip affect the maximum power generated at these various gears?

	Gear	Speed (MPH)	HP	Slip
Tractor 1				
Tractor 2				
Tractor 3				

ASSIGNMENT SHEET #1

4. Plot the test "Varying Drawbar Pull and Travel Speed" for pull and speed.



5. Considering the above material, write a paragraph on the good and poor qualities of the three tractors.

NEBRASKA TRACTOR TEST 1175 – INTERNATIONAL 1568 DIESEL

POWER TAKE-OFF PERFORMANCE

Hp	Crankshaft speed rpm	Fuel Consumption Gal per hr	Fuel Consumption Lb per hp-hr	Hp-hr per gal	Temperature Degrees F Cooling medium	Air wet bulb	Air dry bulb	Barometer inches of Mercury
MAXIMUM POWER AND FUEL CONSUMPTION								
Rated Engine Speed—Two Hours (PTO Speed 1146 rpm)								
150.70	2600	10.089	0.463	14.94	185	63	76	29.063
Standard Power Take-off Speed (1000 rpm)—One Hour								
147.79	2269	9.856	0.463	14.99	195	63	76	29.075
VARYING POWER AND FUEL CONSUMPTION—Two Hours								
131.50	2753	9.089	0.469	14.80	176	63	77	.....
0.00	2848	3.410	.....	.....	163	63	75	.....
69.83	2835	6.073	0.603	11.51	170	64	77	.....
132.12	2600	10.106	0.464	11.96	185	63	76	.....
51.63	2622	4.733	0.949	7.32	165	62	75	.....
103.59	2805	7.490	0.502	13.83	172	62	74	.....
Av 82.45	2774	6.827	0.575	12.08	172	63	76	29.053

DRAWBAR PERFORMANCE

Hp	Drawbar pull lbs	Speed miles per hr	Crankshaft speed rpm	Slip of drivers %	Fuel Consumption Gal per hr	Fuel Consumption Lb per hp-hr	Hp-hr per gal	Temp Degrees F Cooling med	Air wet bulb	Air dry bulb	Barometer inches of Mercury
VARYING DRAWBAR POWER AND FUEL CONSUMPTION WITH BALLAST											
Maximum Available Power—Two Hours—7th Gear (1 Hi TA)											
130.17	8595	5.68	2599	5.65	10.013	0.534	13.00	186	64	76	29.015
75% of Pull at Maximum Power—Ten Hours—7th Gear (1 Hi TA)											
105.44	6615	6.15	2772	4.27	8.612	0.551	12.59	173	58	66	26.919
50% of Pull at Maximum Power—Two Hours—7th Gear (1 Hi TA)											
73.88	4392	6.31	2805	2.83	6.843	0.643	10.80	168	57	62	28.965
50% of Pull at Reduced Engine Speed—Two Hours—8th Gear (1 Hi DD)											
73.92	4403	6.30	2598	3.12	5.979	0.551	12.36	166	58	58	29.000
MAXIMUM POWER WITH BALLAST											
82.71	11918	2.08	2777	14.81	2nd Gear (1 Lo DD)			172	62	73	29.010
128.35	12782	3.77	2600	9.16	3rd Gear (2 Lo TA)			179	62	73	29.060
129.51	10765	4.51	2600	7.08	4th Gear (2 Lo DD)			181	62	73	29.070
130.90	8812	5.57	2600	5.62	6th Gear (3 Lo DD)			180	62	73	29.080
133.79	8812	5.69	2601	5.54	7th Gear (1 Hi TA)			178	63	73	29.090
133.40	7440	6.72	2602	4.75	8th Gear (1 Hi DD)			181	62	73	29.050

VARYING DRAWBAR PULL AND TRAVEL SPEED WITH BALLAST—7th Gear (1 Hi TA)

Pounds Pull		8812	9779	10288	10272	9934	9315
Horsepower		133.79	132.53	125.23	107.86	89.77	73.73
Crankshaft Speed rpm		2601	2539	2076	1821	1561	1298
Miles Per Hour		5.69	5.03	4.49	3.94	3.38	2.82
Slip of Drivers %		5.54	6.16	6.47	6.62	6.47	6.47

TRACTOR SOUND LEVEL (with cab	dB (A)
Maximum Available Power 2 Hours	91.5
75% of Pull at Max. Power 10 Hours	90.0
50% of Pull at Max. Power 2 Hours	91.0
50% of Pull at Reduced Engine Speed 2 Hours	89.0
Bystander 12th Gear (3 Hi DD)	90.0

TIRES, BALLAST AND WEIGHT		With Ballast	Without Ballast
Rear Tires	—No., size, ply & psi	Four 20.8-38, 8; 12	Four 20.8-38, 8; 12
Ballast	—Liquid	545 lb each	None
	Cast Iron	None	None
Front Tires	—No., size, ply & psi	Two 10.00-16, 6; 28	Two 10.00-16, 6; 28
Ballast	—Liquid	None	None
	Cast Iron	110 lb each	None
Height of drawbar		19.5 inches	19.5 inches
Static weight with operator—rear		13700 lb	11525 lb
	front	3630 lb	3425 lb
	total	17330 lb	14950 lb

Department of Agricultural Engineering
Dates of Test: May 5 to May 15, 1975
Manufacturer: INTERNATIONAL HARVESTER COMPANY, 401 NORTH MICHIGAN AVENUE, CHICAGO, ILLINOIS

FUEL, OIL AND TIME Fuel No 2 Diesel Cetane No 51.3 (rating taken from oil company's typical inspection data) Specific gravity converted to 60°/60° 0.8356 Weight per gallon 6.941 lb Oil SAE 30 API service classification CD, CC, CB, CA, SD, SC To motor 3.981 gal Drained from motor 2.752 gal Transmission and final drive lubricant 1H Ty-Tran Fluid Total time engine was operated 53.5 hours.

ENGINE Make INTERNATIONAL Type 8 cylinder Vee Serial No DV-550C12899 Crankshaft Mounted lengthwise Rated rpm 2600 Bore and stroke 4.5" x 4.3125" Compression ratio 16.6 to 1 Displacement 550 cu in Cranking system electric 12 volt Lubrication pressure Air cleaner 2 stage dry type with replaceable pleated paper primary and safety elements and automatic dust unloader Oil filter two replaceable pleated paper full flow screw-on cartridges Oil cooler engine coolant heat exchanger for crankcase oil, radiator for transmission and hydraulic oil Fuel filter two replaceable pleated paper screw-on cartridges Muffler two vertical Cooling medium temperature control one thermostat.

CHASSIS Type standard with duals Serial No 2650127U007470 Tread width rear 62" to 120" front 60.1" to 86.5" Wheel base 104.8" Center of gravity (without operator or ballast, with minimum tread, with fuel tank filled and tractor serviced for operation) Horizontal distance forward from center-line of rear wheels 21.0" Vertical distance above roadway 41.3" Horizontal distance from center of rear wheel tread 0" to the right/left Hydraulic control system direct engine drive Transmission selective gear fixed-ratio with operator controlled, partial range power shift Advertised speeds mph first 1.9 second 2.2 third 4.0 fourth 4.7 fifth 4.9 sixth 5.7 seventh 5.8 eighth 6.8 ninth 12.4 tenth 14.5 eleventh 15.1 twelfth 17.6 reverse 3.3, 3.8, 6.9, 8.1, 8.4, 9.8 Clutch single dry disc, operated by foot pedal with hydraulic power assist Brakes wet single disc; hydraulic power actuated Steering hydrostatic Turning radius (on concrete surface with brake applied) right 143" left 143" (on concrete surface without brake) right 189" left 189" Turning space diameter (on concrete surface with brake applied) right 296" left 296" (on concrete surface without brake) right 387" left 387" Power take-off 1000 rpm at 2269 engine rpm.

REPAIRS AND ADJUSTMENTS: No repairs or adjustments.

REMARKS: All test results were determined from observed data obtained in accordance with SAE and ASAE test code or official Nebraska test procedure.

First gear was not run as it was necessary to limit the pull in second gear to avoid excessive wheel slippage.

Fuel temperature at injection pump was 130°F.

We, the undersigned, certify that this is a true and correct report of official Tractor Test 1175.

L. F. LARSEN
Engineer-in-Charge
G. W. STEINBRUEGGE, Chairman
W. E. SPLINTER
D. E. LANE
Board of Tractor Test Engineers

The Agricultural Experiment Station
Institute of Agriculture and Natural Resources
University of Nebraska – Lincoln
H. W. Ottoson, Director

TRACTOR OPERATION FOR MAXIMUM FUEL EFFICIENCY
UNIT II

Answers to Assignment Sheets

Assignment Sheet #1: Nebraska Tractor Tests

Answers to questions will depend on tractors that are chosen. The author will use the three Nebraska Tractor Tests that are provided as a guide.

1. Tractor 1: International 1568 Diesel
   Tractor 2: Case 1370 Diesel
   Tractor 3: John Deere 4630 Diesel

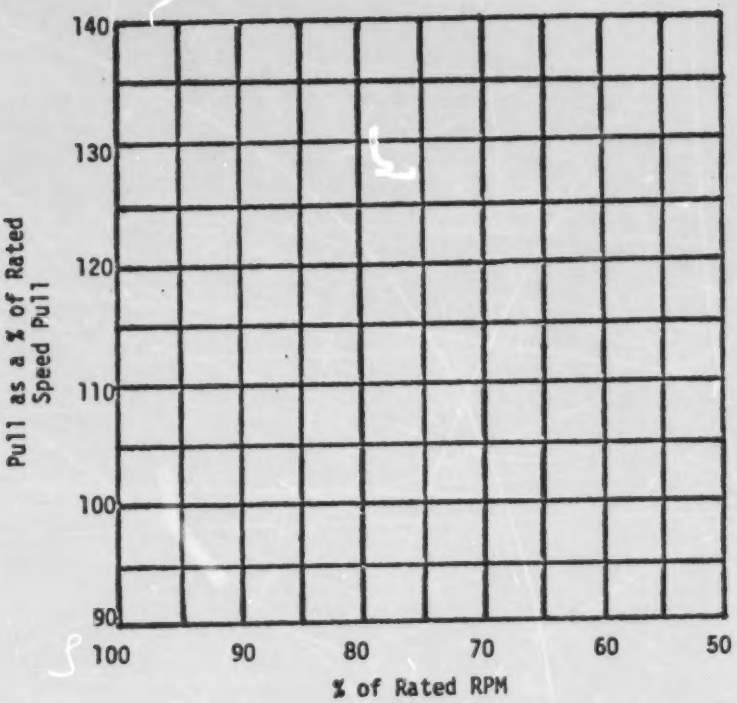
2. Fuel Efficiency at:

	50% Pull	75% Pull	Average PTO
Tractor 1	10.80	12.59	12.08
Tractor 2	9.11	10.91	10.95
Tractor 3	10.59	12.88	12.43

3.

	Gear	Speed (MPH)	HP	Slip
Tractor 1	3rd	4.0	128.55	9.16
	4th	4.7	129.51	7.08
	5th	4.9		
	6th	5.7	130.90	5.62
	7th	5.8	133.79	5.54
	8th	6.8	133.40	4.75
Tractor 2	5th	4.6	131.78	7.65
	6th	5.2	134.25	6.27
	7th	5.8	131.31	5.68
	8th	7.0	131.26	4.63
Tractor 3	4th	4.8	132.02	7.91
	5th	6.2	131.69	4.85

4. Plot the test "Varying Drawbar Pull and Travel Speed" for pull and speed.



5. Considering the above material, write a paragraph on the good and poor qualities of the three tractors.

NEBRASKA TRACTOR TEST 1148 – CASE 1370 DIESEL

POWER TAKE-OFF PERFORMANCE

Hp	Crankshaft speed rpm	Fuel Consumption Gal per hr	Fuel Consumption Lb per hp-hr	Hp-hr per gal	Temperature Degrees F Cooling medium	Air wet bulb	Air dry bulb	Barometer inches of Mercury
MAXIMUM POWER AND FUEL CONSUMPTION								
Rated Engine Speed–Two Hours (PTO Speed–1100 rpm)								
155.56	2200	11.053	0.492	14.07	200	55	74	28.740
Standard Power Take-off Speed (1000 rpm)–One Hour								
156.32	2001	10.415	0.461	15.01	195	69	75	29.030
VARYING POWER AND FUEL CONSUMPTION–Two Hours								
137.76	2287	10.27	0.516	13.41	191	70	76	.....
0.00	2367	3.772	.....	.....	179	70	75	.....
69.96	2332	6.876	0.680	10.17	187	70	76	.....
156.23	2200	11.116	0.492	14.05	197	70	75	.....
35.25	2351	5.319	1.011	6.63	181	72	76	.....
104.15	2309	8.023	0.573	12.98	189	71	75	.....
Av 83.89	2308	7.663	0.652	10.95	187	70	75	29.007

DRAWBAR PERFORMANCE

Hp	Drawbar pull lbs	Speed miles per hr	Crankshaft speed rpm	Fuel Consumption Slip of drivers %	Fuel Consumption Gal per hr	Fuel Consumption Lb per hp-hr	Hp-hr per gal	Temp Degrees F Cooling med	Temp Degrees F Air wet bulb	Temp Degrees F Air dry bulb	Barometer inches of Mercury
VARYING DRAWBAR POWER AND FUEL CONSUMPTION WITH BALLAST											
Maximum Available Power–Two Hours–6th Gear (3 Lo)											
130.93	9847	4.99	2269	6.42	10.874	0.574	12.01	186	44	51	28.980
75% of Pull at Maximum Power–Ten Hours–6th Gear (3 Lo)											
107.76	7568	5.31	2312	4.71	9.880	0.654	10.91	183	33	38	29.331
50% of Pull at Maximum Power–Two Hours–6th Gear (3 Lo)											
71.91	4911	5.49	2335	3.09	7.893	0.759	9.11	185	35	39	29.235
50% of Pull at Reduced Engine Speed–Two Hours–9th Gear (3 Hi)											
30.71	4837	5.48	1309	2.93	5.328	0.521	13.27	182	35	42	29.235
MAXIMUM POWER WITH BALLAST											
103.80	10180	2.41	2293	11.93	2nd Gear (1 Int)			184	40	40	28.990
131.58	11111	4.33	2201	7.65	5th Gear (2 Int)			187	41	48	28.990
134.25	10065	5.90	2200	6.27	6th Gear (3 Lo)			187	38	43	28.850
131.91	8913	5.52	2201	5.68	7th Gear (2 Hi)			187	41	46	28.990
131.26	7255	6.76	2201	4.63	8th Gear (3 Int)			187	41	16	28.990
130.51	5720	8.56	2201	3.71	9th Gear (3 Hi)			187	41	47	28.990

VARYING DRAWBAR PULL AND TRAVEL SPEED WITH BALLAST
6th Gear (3 Lo)

Pounds Pull	10366	11118	12131	12626	12035	10747
Horsepower	134.25	131.50	126.85	115.45	94.53	70.89
Crankshaft Speed rpm	2200	1973	1760	1547	1322	1100
Miles Per Hour	5.90	4.43	3.92	3.43	2.95	2.47
Slip of Drivers %	6.27	7.28	8.11	8.12	8.11	7.00

TRACTOR SOUND LEVEL (with cab)	dB (A)
Maximum Available Power 2 Hours	81.0
75% of Pull at Max. Power 10 Hours	81.5
50% of Pull at Max. Power 2 Hours	84.5
50% of Pull at Reduced Engine Speed 2 Hours	79.5
Bystander 12th Gear (4 Hi)	88.5

TIRES, BALLAST AND WEIGHT		With Ballast	Without Ballast
Rear Tires	–No., size, ply & psi	Four 18.4-38;8;18	Four 18.4-38;8;18
Ballast	–Liquid	1064 lb each	None
	Cast Iron	87 lb each	None
Front Tires	–No., size, ply & psi	Two 10.00-16;6;28	Two 10.00-16;6;28
Ballast	–Liquid	None	None
	Cast Iron	170 lb each	None
Height of drawbar		19 inches	20 inches
Static weight with operator–rear		16150 lb	11545 lb
	front	4140 lb	3800 lb
	total	20290 lb	15345 lb

Department of Agricultural Engineering
Dates of Test: October 31 to November 7, 1975
Manufacturer: J. I. CASE COMPANY, RACINE, WISCONSIN

FUEL, OIL AND TIME Fuel No 2 Diesel Cetane No 50.1 (rating taken from oil company's inspection data) Specific gravity converted to 60°/60° 0.8311 Weight per gallon 6.930 lb Oil SAE 30 API service classification SB/SC CA/CD (MS DS) To motor 4.775 gal Drained from motor 4.167 gal Transmission and final drive lubricant CASE TFD fluid Total time engine was operated 19 hours.

ENGINE Make J. I. Case Diesel Type 6 cylinder with turbo-charger Serial No 2530115 Crankshaft Mounted lengthwise Rated rpm 2200 Bore and stroke 4¼" x 5" Compression ratio 15.8 to 1 Displacement 504 cu in Cranking system 12 volt electric Lubrication pressure Air cleaner dry type two stage with replaceable pleated paper elements and precleaner Oil filter two parallel full flow replaceable cartridges Oil cooler engine coolant heat exchanger for crankcase oil and radiator for transmission and hydraulic fluid Fuel filter replaceable primary and secondary filter cartridges Muffler was used Cooling medium temperature control two thermostats.

CHASSIS Type standard Serial No 8731352 Tread width rear 62" to 108" front 60" to 1[illegible] Wheel base 104" Center of gravity (without operator or ballast with minimum tread, with fuel tank filled and tractor serviced for operation) Horizontal distance forward from [illegible] line of rear wheels 29.7" Vertical [illegible] above roadway 39.2" Horizontal distance [illegible] center of rear wheel tread 0" to the right Hydraulic control system direct engine drive Transmission selective gear lever ratio with partial range operator controlled power reverse Advertised speeds mph first 2.0 second 2.5 third 3.4 fourth 3.5 fifth 4.6 sixth 5.2 seventh 5.[illegible] eighth 7.0 ninth 8.8 tenth 11.2 eleventh 14.[illegible] twelfth 18.5 reverse 3.4, 5.8 and 8.8 Clutch multiple disc wet clutches within transmission actuated hydraulically Brakes wet multiple disc hydraulically power actuated by two foot pedals that can be locked together Steering hydrostatic Turning radius (on concrete surface with brake applied) right 148" left 146" (on concrete surface without brake) right 172" left 172" Turning space diameter (on concrete surface with brake applied) right 307" left 307" (on concrete surface without brake) right 356" left 356" Power take-off 1030 rpm at 2000 engine rpm.

REPAIRS and ADJUSTMENTS: The intake manifold cup plug came out during the PTO run causing a loss in power. The plug was replaced and test continued.

REMARKS: All test [illegible] were determined from observed data obtained in accordance with SAE and ASAE test code or official Nebraska test procedure.

First gear was not run as it was necessary to limit the pull in second gear because of excessive wheel slippage. Third, fourth, tenth, eleventh, and twelfth gears were not run as test procedure requires only six travel speeds.

We, the undersigned, certify that this is a true and correct report of official Tractor Test 1148.

L. F. LARSEN
Engineer-in-Charge
G. W. STEINBRUEGGE, Chairman
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Board of Tractor Test [illegible]ers

The University of Nebraska Agricultural Experiment Station
H. W. Ottoson, Director & Acting Dean; Lincoln, Nebraska
E-34

ENERGY AND AGRICULTURE

UNIT II

ANSWERS TO ASSIGNMENT SHEET

Answers to questions will depend on tractors that are chosen. The author will use the three Nebraska Tractor Tests that are provided as a guide.

1. Tractor 1: International 1568 Diesel

   Tractor 2: Case 1370 Diesel

   Tractor 3: John Deere 4630 Diesel

2.

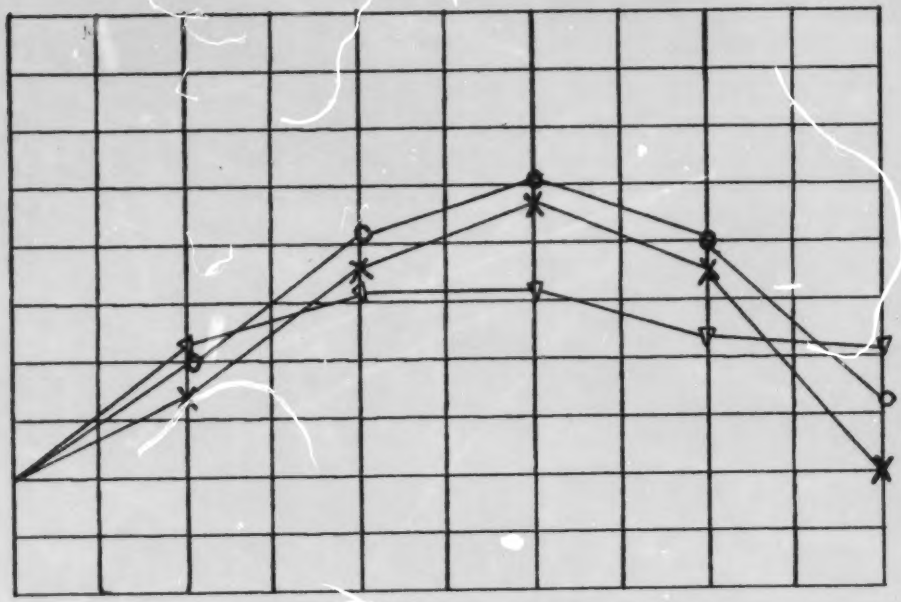
Fuel Efficiency at:	50% Pull	75% Pull	Average PTO
Tractor 1	10.80	12.59	12.08
Tractor 2	9.11	10.91	10.95
Tractor 3	10.59	1[illegible].88	12.43

3.

	Gear	Speed (MPH)	HP	Slip
Tractor 1	3rd	4.0	128.55	9.16
	4th	4.7	129.51	7.08
	5th	4.9		
	6th	5.7	130.90	5.62
	7th	5.8	133.79	5.54
	8th	6.8	133.40	4.75
Tractor 2	5th	4.6	131.78	7.65
	6th	5.2	134.25	6.27
	7th	5.8	131.31	5.68
	8th	7.0	131.26	4.63
Tractor 3	4th	4.8	132.02	7.91
	5th	6.2	131.69	4.85

ANSWERS TO ASSIGNMENT SHEET

4.



Tractor 1 ▽——▽

Tractor 2 o——o

Tractor 3 x——x

5. The answer to this question should consider all of the factors listed in part IV of the Information Sheets.

Consideration of the fuel economy of the three tractors seems to indicate that the International 1568 and John Deere 4630 have an advantage. These two tractors are between 10 and 20% more fuel efficient than the Case 1370.

All tractors had approximately the same maximum PTO and drawbar horsepower. If the drawbar horsepower varies considerably on tractors with similar PTO horsepower, one should check the slip rate listed in the tests. On concrete, 4 to 8% slip is ideal. If the slip rate is outside this range, one would expect a reduced drawbar horsepower. If this is not the case, the loss of horsepower may be due to transmission or friction losses. In the tractors chosen by the author, slip rates during the tests were acceptable and no major difference was noted in drawbar horsepower.

ANSWERS TO ASSIGNMENT SHEET

5. The International tractor had the most gears in the range of normal field speeds. However, they were not evenly spaced. The case tractor has approximately the same number of choices of speeds for field operations as the International tractor despite having fewer gears in this range. The John Deere tractor offers an operator little choice of gear selection and speed for field operation. One should also notice that the advertized speeds for various gears are usually higher than those reported by the Nebraska Tractor Tests.

All tractors demonstrate a good pull rise during the initial 20% reduction of speed. The pull rise after this point should be of little concern.

ENERGY AND AGRICULTURE

UNIT II

TEST

1. Match the definitions on the right with the correct term in the space provided.

_____a.	Drawbar horsepower	1.	The rate of doing work
_____b.	Draft	2.	The power available at the power take off shaft
_____c.	Fuel efficiency	3.	Power required to pull a towed or mounted implement
_____d.	PTO horsepower	4.	The horizontal force exerted by a tillage implement
_____e.	Power	5.	A force acting through a displaced distance
_____f.	Work	6.	A ratio of the power generated to the fuel consumed per hour

2. Compare the fuel consumption for a diesel, gasoline, and LP-gas tractor by inserting the type of fuel used by each to complete this statement.

   A _____ fueled tractor uses 30% more fuel than a _____ tractor and a _____ fueled tractor uses the least fuel of all three.

3. Place an X by the major reasons for the differences in fuel efficiency for a diesel engine, gasoline, or LP-gas engine.

_____a. LP-gas has more energy per gallon of fuel than does gasoline or diesel fuel.

_____b. The higher compression ratio of diesel engine results in higher fuel efficiency.

_____c. Diesel engines operate at higher RPM than gasoline and LP-gas engines resulting in higher fuel efficiency.

_____d. Less friction is involved in a diesel engine rather than a gasoline or LP-gas engine.

_____e. Diesel fuel has a higher energy content per gallon than does a gasoline or LP-gas.

TEST

4. List the major types of tests run for Nebraska Tractor Tests.

   a.

   b.

   c.

5. List the major factors to consider when comparing tractors by use of Nebraska Tractor Tests.

   a.

   b.

   c.

   d.

ENERGY AND AGRICULTURE

UNIT II

ANSWERS TO TEST

1. a. 3 d. 2
   b. 4 e. 1
   c. 6 f. 5

2. LP-gas, gasoline, diesel

3. The following should have an X:
   b. e.

4. a. Power take off performance tests
   b. Drawbar performance tests
   c. Sound level tests

5. a. Fuel efficiency of drawbar tests at 50% and 75% of pull at maximum power level and average PTO fuel efficiency.
   b. Maximum power available at drawbar.
   c. Number of gears and gear spacing for those normally used in field operation.
   d. Increase in tractor pull for drops in speed.

ENERGY AND AGRICULTURE

UNIT III

TRACTOR OPERATION FOR MAXIMUM FUEL EFFICIENCY

TERMINAL OBJECTIVE

Upon completion of this unit, students will be able to calculate and check in the field for proper ballasting (weighting) of a tractor and understand operational practices such as proper matching of tillage equipment to the tractor, gear up and throttle down, and minimized idling. This objective will be considered achieved by scoring at least eighty-five percent on the test.

SPECIFIC OBJECTIVES

After completion of this unit, students will be able to:

1. Match terms with the correct definitions.
2. List two major causes of power loss between PTO horsepower and drawbar horsepower and calculate these losses.
3. List the results of too little, too much, and correct ballasting on driving tires.
4. List five reasons for proper ballasting and tire selection.
5. List three factors affecting tractor weight requirements.
6. Determine the proper ballasting of front and rear tires for a two wheel drive tractor.
7. Determine proper tractor tire carrying capacity size and tire inflation pressure.
8. Recognize the major reasons for matching tillage implement size and tractor power.
9. Determine the maximum implement width for given tractor.
10. State the major guidelines of gear up and throttle down.
11. List the three reasons for gear up and throttle down practices.
12. State three reasons why idling of a tractor is wasteful of fuel.

ENERGY AND AGRICULTURE

UNIT III

SUGGESTED ACTIVITIES

Instructor:

1. Provide students with Objective Sheet
2. Provide students with Information, Assignment, and Job Sheets
3. Make Transparencies
4. Discuss Terminal and Specific Objectives
5. Discuss Information and Assignment Sheets
6. Discuss and demonstrate Job Sheet
7. Give Test

Students:

1. Read Objectives
2. Study Information Sheets
3. Complete Assignment Sheet and turn in to instructor
4. Participate in Job Sheet demonstration
5. Take Test

INSTRUCTIONAL MATERIALS

Included in this unit:

1. Objectives
2. Information Sheets
3. Transparency Masters

   TM 1 - TRACTIVE EFFICIENCY

   TM 2 - TYPICAL DRAWBAR HP RESULTS FOR A 150 PTO HP TRACTOR UNDER DIFFERENT SOIL CONDITIONS

   TM 3 - EFFECT OF SLIP

   TM 4 - RECOMMENDED WEIGHT FOR VARIOUS SPEEDS

INSTRUCTIONAL MATERIALS

TM 5 - VISUAL CHECK OF TIRE SLIPPAGE

TM 6 - LOAD CAPACITIES AND INFLATION PRESSURES

TM 7 - SOIL RESISTANCE

4. Assignment Sheet

   #1 - Proper Ballasting of a Tractor and Matching of Tillage Implement and Tractor

5. Answers to Assignment Sheet

6. Job Sheet

   #1 - Checking Tractor Tire Slippage in the Field

7. Test

8. Answers to Test

References:

1. Herron, Maynard. "Gear Up -- Throttle Down," Kansas State University Extension Publication EN-FC2, September, 1976.

2. Bowers, Wendell. Fundamentals of Machinery Operation: Machinery Management, John Deere Service Publications, Moline, Illinois, 1975.

3. Wilkinson, Robert H., & Bill A. Stout. Wheel Slip and Proper Tractor Weight for Maximum Efficiency. Michigan State University Extension Publication, Agricultural Engineering Information Series, July, 1978.

4. Posselius, John, and Bill A. Stout. Saving Energy (and $) While Operating a Tractor. Michigan State University Extension Publications, Agricultural Engineering Information Series, July, 1978.

ENERGY AND AGRICULTURE

UNIT III

INFORMATION SHEET

I. Terms and Definitions

A. Allowable implement width - Greatest amount of tillage implement width that a given tractor can pull

$$\text{Width (FT.)} = \frac{\text{Tractor Draft (LBS)}}{\text{Implement Draft (LBS/FT.)}}$$

B. Axle HP - PTO HP - (0.04 x PTO HP)

C. Ballast - Weight added or removed from a tractor to change its total weight or weight distribution to each tire.

D. Draft (LBS) - Horizontal force in LBS $= \frac{\text{Drawbar HP x 375}}{\text{MPH}}$

E. Drawbar HP - Tractive efficiency x Axle HP

F. Slip - Tractor tire revolves more times under load than it would to cover the same distance under no load

$$\% \text{ of slip} = \frac{\text{Loaded Rev. - No load Rev.}}{\text{Loaded Revolutions}} \times 100$$

G. Tractive efficiency - Ratio of drawbar HP to HP delivered to the axle (Given as a percent)

II. Power Losses of a Tractor

A. Losses from transmission

1. Transmission losses average 4%

2. Axle Horsepower = PTO Horsepower - (0.04 X PTO Horsepower)

B. Losses between tractor tire and soil = tractive efficiency (TM 1,2)

1. Depends on soil condition as firm, tilled, or sandy

2. Drawbar HP = Tractive Efficiency (T.E.) X Axle HP

3. Example

A tractor can produce 150 HP at the PTO shaft.
Axle Horsepower = 150 HP - (0.04 x 150 HP) = 144 HP

INFORMATION SHEET

TYPICAL DRAWBAR HP RESULTS FOR A 150 PTO HP TRACTOR UNDER DIFFERENT SOIL CONDITIONS

No.	Soil Type	% Slip	T.E.	Drawbar hP
1	Firm	10	78%	112
2	Firm	25	64%	92
3	Firm	3	64%	92
4	Sandy	15	52%	75
5	Tilled	12	64%	92

III. Results of Tire Ballasting (TM 3)

A. Too little ballasting on driving tires causes high slippage and lost power

B. Too much ballasting on driving tires causes high rolling resistance and lost power

C. Correct ballasting on rear tires should allow slip to be 8 to 15%, this range will allow development of the maximum possible drawbar horsepower

IV. Proper Ballasting and Tire Selection

A. Reasons for proper ballasting

1. Allows tractor to produce maximum potential horsepower

2. Allows tractor to operate at higher fuel efficiency

3. Avoids excessive stress on transmission, resulting from too much ballasting

4. Avoids excessive tire wear, resulting from too little ballasting

5. Avoids excessive soil compaction, resulting from too much ballasting

V. Factors Affecting Tractor Weight Requirements

A. Type of implement

1. Mounted and semi-mounted implements transfer some weight from the front tires to the rear tires

2. Less weight is transferred by a towed implement

INFORMATION SHEET

B. Soil type

C. Draft or load

VI. Determining the Proper Ballasting of Tractor Tires (TM 5)

A. Weight on front tires of two wheel drive tractor

1. Only enough weight on front end to maintain good control during field operation

2. One third of total tractor weight should be on front end for mounted implements

3. One fourth of total tractor weight should be on front end for towed implements

B. Weight on rear tires of two wheel drive tractor (Follow recommendations of TM 4)

1. Example - Two wheel drive 150 PTO HP tractor travels through field at 5 mph pulling a towed implement.

Proper ballasting = 150 HP X 100 LBS/HP
= 15,000 LBS on rear tires

C. Check slippage in field as described by Job Sheet #1

VII. Determining Proper Tractor Tire Size for Carrying Capacity and Inflation Pressures (TM 6)

A. Driving tire inflation pressure should be no less than 16 psi for singles and 12 psi for duals, low pressure reduces soil compaction but also lowers the load carrying capacity of the tire

B. Carrying Capacity - do not overload tires

1. For two wheel drive tractor, assume each rear tire will carry an equal portion of weight on the rear axle

2. For a four wheel drive tractor, assume each tire will carry equal portion of entire tractor weight

C. Check tires for side wall buckling in field under load

VIII. Reasons for Matching Tractor to Tillage Implement

A. Allows operation at recommended tillage speeds while operating at near maximum loads

INFORMATION SHEET

B. Fuel efficiency is best when operating near maximum load

C. Avoids extended overloading of engine and drive train

D. Avoids high cost per unit work from too small an implement used for too large a tractor

IX. Determining the Maximum Implement Width for a Given Tractor (TM 1,7)

A. Determine maximum drawbar HP based on field conditions

1. Example - 150 PTO HP tractor slipping 12% in tilled soil

B. Determine draft based on 80% of maximum drawbar HP

$$\text{Drawbar HP} = \frac{\text{Draft} \times \text{MPH}}{375} \qquad \text{Total Draft} = \frac{\text{Drawbar HP} \times 375}{\text{MPH}}$$

1. Example - Drawbar HP = 92 HP or $[150 - (.04 \times 150)] \times .64 = 92$

Desired travel speed is 5 mph

$$\text{Total Draft} = \frac{0.08 \times 92 \times 375}{5} \qquad \text{Total Draft} = 5520 \text{ LBS}$$

C. Determine implement width

$$\text{Width (feet)} = \frac{\text{tractor draft}}{\text{draft per foot}}$$

1. Example - Tillage implement, offset disk, operated in medium draft conditions

$$\text{Width} = \frac{5520 \text{ LBS}}{325 \text{ LBS/FT}} = 17 \text{ FT}$$

X. Gear Up and Throttle Down

A. General guidelines

1. Reduce RPM by 20% and gear up to maintain ground speed

2. Use only for medium and light loads (3/4 of maximum power or less)

3. Stay within working RPM range specified by owner's manual

4. Don't overload engine, occassionally check if engine will respond to throttle opening

XI. Reasons Enabling Gear Up-Throttle Down Practices

A. Tractors often overpowered for tillage operations

1. Tractors operate at an average of 55% of maximum power

INFORMATION SHEET

2. Gear up and throttle down could be used for 80% of all tractor operations (see Table 1)

B. Fuel savings of 15 to 30% can occur with reduction of RPM for partial loads

C. Nebraska tractor tests show savings for throttling back when under less than full loads (see 50% of Pull at Reduced Engine speed under Drawbar Performance- Nebraska Tractor Tests)

Note: Misconceptions

1. Turbocharged engines must be operated at full throttle

2. Turbocharged and natural air intake engines can operate at reduced RPM with no problems if:

a. Engine is not overloaded for any extended periods

b. Operated at lower RPM setting than is recommended by the manufacturer

Table 1: Percentage of Time Tractors Operate at Selected Levels of Power (Ref. 2)

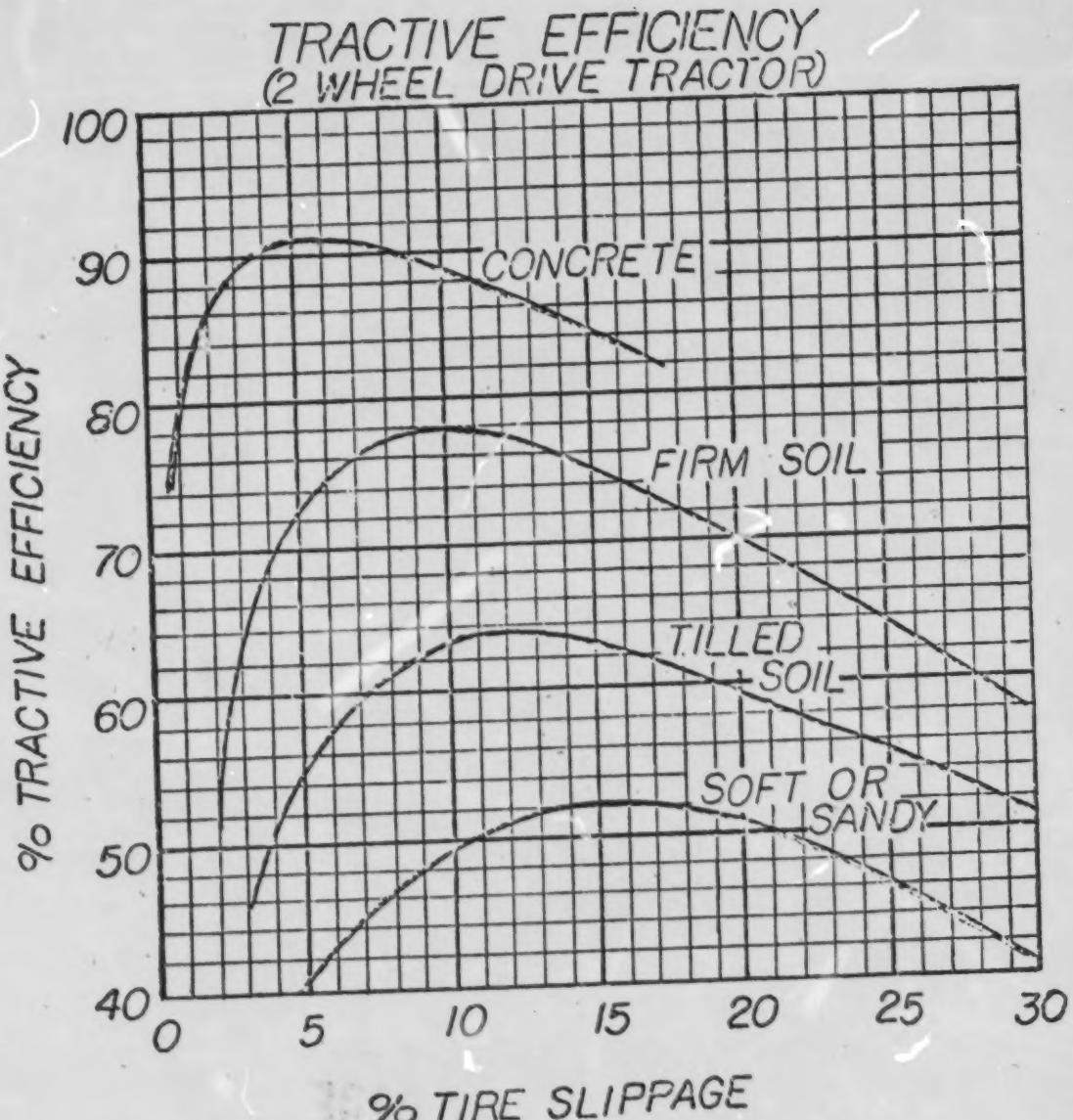
Maximum Power Percentage	Total Time Percentage
Over 80%	16.8%
60 to 80%	23.9%
40 to 60%	22.6%
20 to 40%	17.5%
Under 20%	19.2%

XII. Idling Wastes Fuel

A. The average tractor idles for more than 12% of its total operational time

B. A 145 HP diesel tractor uses a half gallon of fuel per hour at an idle

C. A tractor idling may use 42% as much fuel as it would under full load


TRACTIVE EFFICIENCY
(2 WHEEL DRIVE TRACTOR)
100
90
80
70
60
50
40
% TRACTIVE EFFICIENCY
CONCRETE
FIRM SOIL
TILLED SOIL
SOFT OR SANDY
0
5
10
15
20
25
30
% TIRE SLIPPAGE

Typical Drawbar Hp Results For a 150 PTO Hp Tractor Under different Soil Conditions

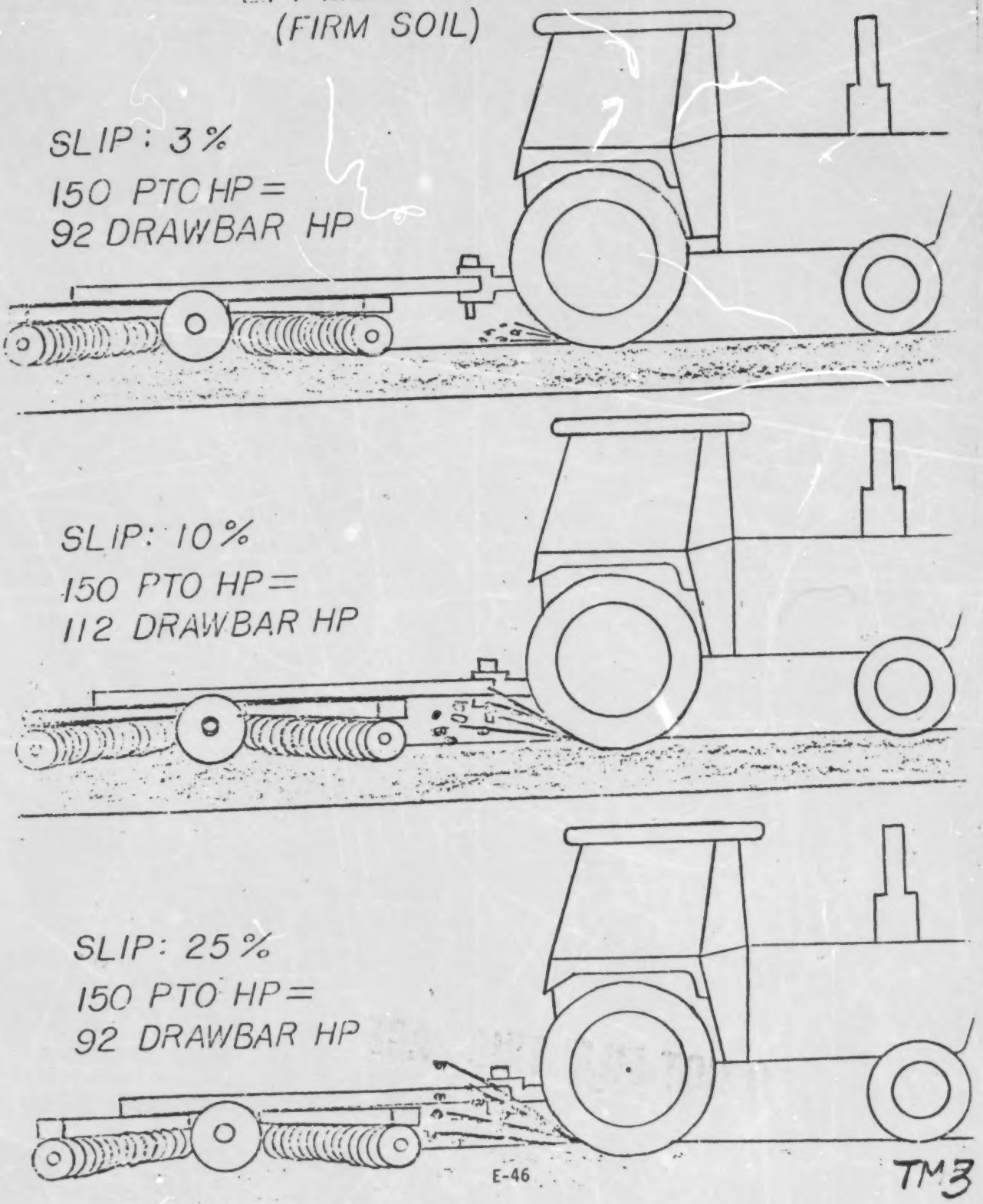
NO.	Soil type	% Slip	T.E.	Drawbar Hp
1	Firm	10	78%	112
2	Firm	25	64%	92
3	Firm	3	64%	92
4	Sandy	15	52%	75
5	Tilled	12	64%	92

EFFECT OF SLIP
(FIRM SOIL)

SLIP: 3%
150 PTO HP =
92 DRAWBAR HP

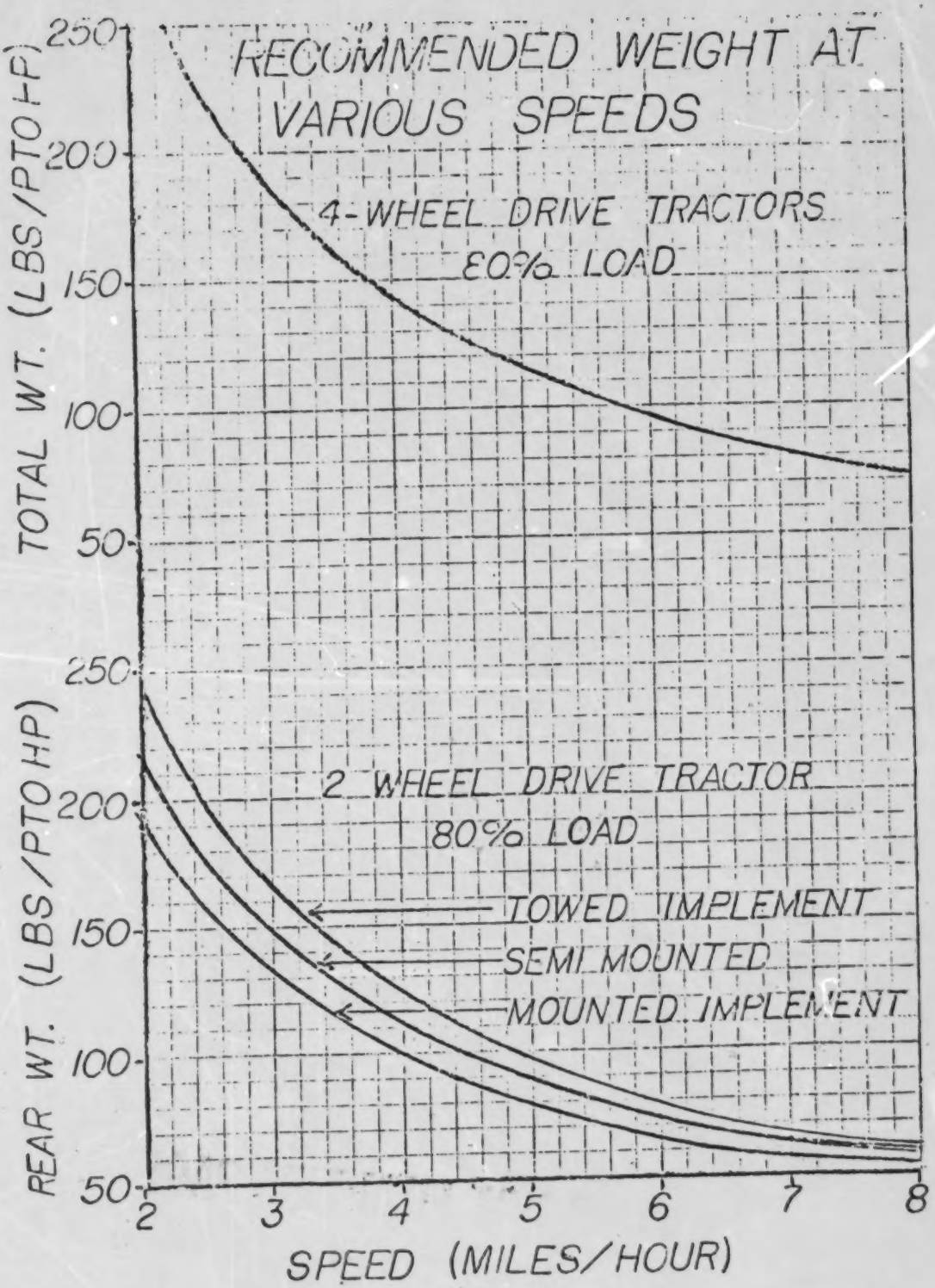
SLIP: 10%
150 PTO HP =
112 DRAWBAR HP

SLIP: 25%
150 PTO HP =
92 DRAWBAR HP



E-46

TM3


RECOMMENDED WEIGHT AT VARIOUS SPEEDS
4-WHEEL DRIVE TRACTORS
80% LOAD
2 WHEEL DRIVE TRACTOR
80% LOAD
TOWED IMPLEMENT
SEMI MOUNTED
MOUNTED IMPLEMENT
TOTAL WT. (LBS/PTO HP)
REAR WT. (LBS/PTO HP)
250
200
150
100
50
2
3
4
5
6
7
8
SPEED (MILES/HOUR)

E-45

TM 4

Visual Check of Tire Slippage

Too Little Too Much Proper Weight

Too little------When the weight on the tires is too little, the tread marks are wiped out entirely due to excessive slippage, which reduces forward progress.

Too much--------When too much weight is used, the tire tracks will be sharp and distinct in the soil.

Proper weight---When the tires are weighted properly, a small amount of slippage occurs. The soil between the cleats of the tire pattern is shifted but the tread pattern is still visible.

~~Table 2~~. Load Capacities and Inflation Pressures* ~~(Ref. 2)~~

	Single		Dual	
Tire Size	Minimum Recommended Pressure (PSI)	Maximum Load Capacity at Minimum Pressure (LBS)	Minimum Recommended Pressure (PSI)	Maximum Load Capacity at Minimum Pressure (LBS)
15.5-38	14	3160	12	2540
16.9-30	16	3900	...	...
16.9-34	16	4140	12	3080
16.9-38	16	4380	12	3260
18.4-30	16	4680	...	...
18.4-34	16	4970	12	3700
18.4-38	16	5250	12	3910
20.8-34	16	6010	12	4470
20.8-38	16	6360	12	4730
23.1-26	16	6280	12	4670
23.1-30	16	6700	12	4980
23.1-34	16	7110	12	5290
24.5-32	18	8180	12	5680
28L-26	16	7280	12	5410
30.5L-32	16	9120	12	6780

*All loads are given for individual tires based on Tire and Rim Association standards.

TM 6

Table 3. Soil Resistance ~~(Ref. 5)~~

Operation	Pounds of Draft Per Foot of Width	Typical Speed MPH
Plowing (8 inches deep)		
Gumbo	1250	4.0
Clay	1050	4.0
Loam	950	4.5
Sandy Loam	700	5.0
Sand	350	5.0
Chisel Plowing (8 inches deep)		
Hard Dry Soil	800	4.0
Medium Clay Loam		
Good Moisture	500	5.0
Sand, Sandy Loam	200	6.0
Tandem Disk Harrow		
Heavy Draft	300	4.0
Medium Draft	200	5.0
Light Draft	100	6.0
Offset or Heavy Tandem Disk		
Heavy Draft	400	4.0
Medium Draft	325	5.0
Light Draft	250	6.0
Oneway Disk		
Heavy Draft	400	4.0
Medium Draft	300	5.0
Light Draft	200	6.0
Field Cultivator		
Heavy Clay Soils or Dry Hard Conditions	650	4.0
Clay Loam	450	5.0
Sandy Loam	300	5.0
Sand	150	6.0

Caution: Draft values are heavily dependent on tillage depth, soil moisture, speed of operation, and tillage implement design. Above values represent average values only. One should rely heavily on past individual experience when sizing new tillage equipment or choosing tractor horsepower level.

ENERGY AND AGRICULTURE

UNIT III

ASSIGNMENT SHEET #1: Proper Ballasting of a Tractor and Matching of Tractor and Tillage Implement

1. For a tractor producing 125 PTO HP, what quantity of horsepower will be delivered to the axle?

2. For the tractor in question #1, what is the maximum horsepower that can be delivered to the drawbar under the following conditions?

   a. Concrete

   b. Firm soil

   c. Tilled soil

   d. Soft or sandy soil

3. What quantity of drawbar horsepower will be lost under the conditions of question #2 if the tractor is slipping 25% instead of being properly ballasted?

   a. Firm soil

   b. Tilled soil

   c. Soft or sandy soil

4. For the tractor operated on your family's farm, determine the following information:

   a. Maximum PTO HP

ASSIGNMENT SHEET #1

b. Maximum Axle HP

c. Soil Conditions

d. Maximum possible Drawbar HP

5. Determine the proper weight on the rear and front axle [illegible] wheel drive, 125 PTO HP tractor operating at an 80% load under the following conditions:

   a. Towed implement pulled at 5 MPH

   b. Mounted implement pulled at 6 MPH

6. Will single or dual rear tires be necessary to meet load capacity requirements at minimum recommended pressures for the following rear axle weights and tire sizes?

	Weight on rear axle	Tire size	Circle One		
a.	12000 LBS	18.4-38	Single	Dual	Neither
b.	16000 LBS	24.5-32	Single	Dual	Neither
c.	17000 LBS	18.4-38	Single	Dual	Neither

7. A properly ballasted 150 HP PTO tractor is available for field work.

   a. Considering both transmission power losses and losses between tire and soil, what is the maximum drawbar power available in sandy soil?

   Based on an 80% load and a desired speed of 6 mph, what is the draft?

   What should be the approximate width of a chisel plow operating at a depth of 8 inches in sandy loam soil?

ASSIGNMENT SHEET #1

b. Considering both transmission power losses and losses between tire and soil, what is the maximum drawbar power available in a stubble field?

Based on an 80% load and a desired speed of 4 mph, what is the draft?

What should be the approximate width of an offset disk operating under heavy draft conditions?

ENERGY AND AGRICULTURE

UNIT III

ANSWERS TO ASSIGNMENT SHEET

1. 120 HP

2. a. At 6 to 7% slip, tractive efficiency equals 91%.
   Drawbar HP = 109 HP

   b. At 9 to 10% slip, tractive efficiency equals 78%.
   Drawbar HP = 94 HP

   c. At 12% slip, tractive efficiency equals 64%.
   Drawbar HP = 77 HP

   d. At 15% slip, tractive efficiency equals 52%.
   Drawbar HP = 62 HP

3. a. Tractive efficiency = 64% Lost drawbar HP = $94 - \frac{64 \times 120}{100} = 17$ HP

   b. Tractive efficiency = 55% Lost drawbar HP = 11 HP

   c. Tractive efficiency = 46% Lost drawbar HP = 7 HP

4. Dependent on individual situation

5. a. Rear Weight = 100 LBS/PTO HP x 125 PTO HP = 12,500 LBS

   Front Weight = $\frac{\text{Total Weight}}{4} = \frac{\text{Rear Weight}}{3}$ = 4167 LBS

   b. Rear Weight = 67 LBS/PTO HP x 125 PTO HP = 8375 LBS

   Front Weight = $\frac{\text{Total Weight}}{3} = \frac{\text{Rear Weight}}{2}$ = 4188 LBS

6. a. Duals

   b. Singles: A little extra tire pressure may be necessary to increase load capacity. This will give a greater safety factor.

   c. Singles or duals will not carry weight. One must either increase tire pressure or get larger tires.

7. a. Maximum drawbar HP in sandy soil = 75 HP Draft = 3750 LB

   Width = 18.75 feet or 19 feet

   b. Stubble field is considered firm soil.

   Maximum drawbar HP = 112 HP Maximum implement width = 21 feet

   Draft = 8400 LB

ENERGY AND AGRICULTURE

UNIT III

JOB SHEET #1: Checking Tractor Tire Slippage in the Field

I. Tools and equipment needed:

A. Tractor

B. Tillage implement. It should be typical of tillage equipment normally used on a farm.

C. Two stakes

D. Bright colored spray paint

II. Procedure:

A. If possible, determine total tractor weight and weight on front and rear axle. Next ballast tractor according to recommendations of Information Sheet U3-6 (VI.) and TM 4.

B. Choose a field, working conditions, and implement that are typical of the work you do. Operate tractor in the same gear and throttle setting as usual.

C. Place a single mark on the rear tire so that the mark can be easily seen from the side of the tractor.

D. Position a starting stake at an arbitrary point.

E. With the implement in the ground, drive past the stake and note the position of the mark on the tire. Allow extra space to get tractor up to speed when it crosses starting point.

F. Walk alongside the tractor and count 10 full revolutions of the rear tire. Place a finish stake at this point.

G. Circle back with the tool out of the ground. Use the same or lower gear and do not drive on previously worked ground. Hopefully, the rear tire will not be slipping during the unloaded pass.

H. Count the number of revolutions of the rear tire required to travel the distance between two stakes with the implement out of the ground.

I. Calculate the percent of slip.

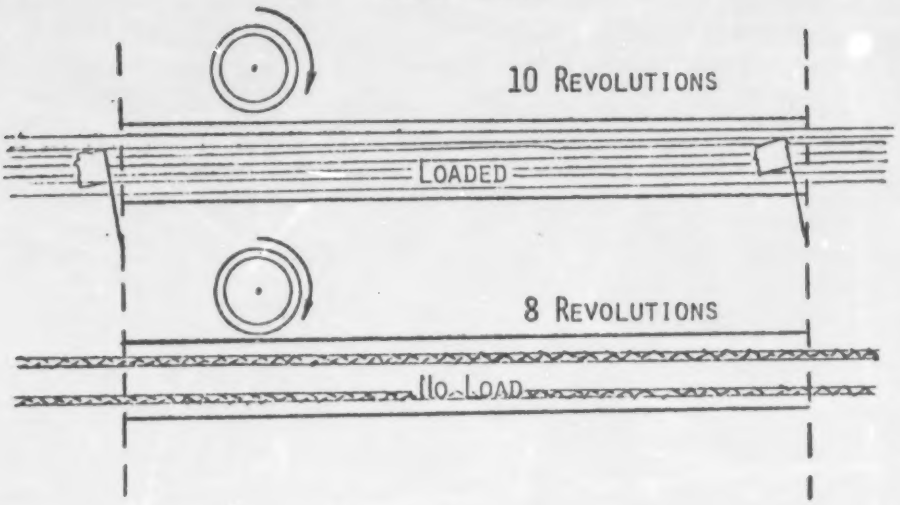
$$\% \text{ slip} = \frac{10 - \text{revolutions without load}}{10} \times 100$$

JOB SHEET #1

J. Add or subtract weight to move towards point of maximum tractive efficiency.

K. Check slip at new weight level.

WHEEL SLIP



$$\% \text{ SLIPPAGE} = \frac{\text{LOADED REV.} - \text{NO LOAD REV.}}{\text{LOADED REV.}} \times 100$$

$$= \frac{10 - 8}{10} \times 100$$

$$= .2 \times 100$$

$$\text{SLIP} = 20\%$$

ENERGY AND AGRICULTURE

UNIT III

TEST

Note: Transparency Masters 1, 4, and 6 will be needed during the test.

1. Match the definitions on the right with the correct term in the space provided.

_____a. Allowable implement width	1. Weight added or removed from a tractor to change its total weight or weight distribution
_____b. Axle HP	2. Tractor tire revolves more times under load than it would to cover same distance under no load
_____c. Ballast	3. $\frac{\text{Tractor draft (LBS)}}{\text{Implement draft (LBS/FT)}}$
_____d. Draft (lbs)	4. Ratio of drawbar HP to HP delivered to the axle.
_____e. Drawbar HP	5. $\frac{\text{Drawbar HP x 375}}{\text{MPH}}$
_____f. Slip	6. PTO HP - (0.04 x PTO HP)
_____g. Tractive efficiency	7. Tractive efficiency X Axle HP

2. a. List the two major causes for the power loss between PTO horsepower and drawbar horsepower.

   1.

   2.

   b. A 100 PTO HP tractor is slipping 20% in tilled soil. What is the horsepower delivered to the axle and the drawbar horsepower?

   1. Axle horsepower

   2. Drawbar horsepower

3. List the results of too little, too much, and correct ballasting of drive tires.

   Too little causes:

   Too much causes:

   Correct amount allows:

TEST

4. List five reasons for proper ballasting and tire selection.

   a.

   b.

   c.

   d.

   e.

5. List three factors affecting tractor weight requirements.

   a.

   b.

   c.

6. Determine the proper ballasting of front and rear tires for a 100 PTO HP tractor loaded 80% of maximum load. Tractor is pulling a towed implement at 6 MPH.

   a. Weight on front axle? _____

   b. Weight on rear axle? _____

7. Determine proper tractor tire carrying capacity size and tire inflation pressure given a tractor with 14,000 LBS on rear axle and 34" diameter rims.

   a. Tire size _____ X 34

   b. Tire pressure _____PSI

8. Place X by major reasons for matching tillage implement size to tractor's available power.

   _____a. Proper matching avoids extended overloads on the tractor engine.

   _____b. Proper matching reduces need for air cleaner maintenance.

   _____c. Proper matching allows operation of tractor at a more fuel efficient level.

   _____d. Proper matching reduces front end ballast requirements of tractor.

TEST

9. Determine the maximum implement width and total draft based on an 80% load with a tractor that produces 75 HP at the drawbar and is pulling a chisel at 4 MPH. The chisel has a draft of 400 LB/FT.

10. State the major guidelines for gear up and throttle down.

    a.

    b.

    c.

    d.

11. List the three reasons for gear up and throttle down.

    a.

    b.

    c.

12. State three reasons why idling of a tractor is wasteful of fuel.

    a.

    b.

    c.

ENERGY AND AGRICULTURE

UNIT III

ANSWERS TO TEST

1. a. 3
   b. 6
   c. 1
   d. 5
   e. 7
   f. 2
   g. 4

2. a. 1. Transmission losses
      2. Losses between tire and soil
   b. 1. 96 HP
      2. 57 HP

3. Too little causes: high slippage and lost power
   Too much causes: high rolling resistance and lost power
   Correct amount allows: between 8-15% slip and maximum HP

4. a. Allows maximum produced power
   b. Allows highest fuel efficiency
   c. Avoids excessive stress on transmission
   d. Avoids excessive tire wear
   e. Avoids excessive soil compaction

5. a. Type implement - mounted transfers some weight to rear tires where towed implements add little weight
   b. Soil type
   c. Draft or load

6. a. 2,667 LBS
   b. 8,000 LBS

7. a. 23.1
   b. 16

8. The following should have an X:
   a.
   c.

ANSWERS TO TEST

9. Draft = 5,625 LB
   Width = 14 feet

10. a. Reduce RPM by 20% and gear up
    b. Use only for medium and light loads (75% of maximum power or less)
    c. Stay within owner's manual working RPM range
    d. Do not overload engine

11. a. Tractors often overpowered and use only an average of 55% of maximum power.
    b. Fuel savings of 15-30% could occur.
    c. Tests show savings for throttling back when under less than full loads.

12. a. Average tractor idles 12% of its total operational time.
    b. 145 HP diesel uses 1/2 gal. of fuel per hour at an idle.
    c. Tractor idling may use as much as 42% fuel as at full load.

ENERGY AND AGRICULTURE

UNIT IV

PETROCHEMICAL AGRICULTURE

TERMINAL OBJECTIVE

Upon completion of this unit, students will be able to define terms related to petrochemical energy use in agriculture, recognize the amounts of energy these represent and state or discuss various practices in the use of petrochemicals or alternatives to their use in farming.

SPECIFIC OBJECTIVES

After completion of this unit, students will be able to:

1. Match petrochemical energy related terms with the correct definitions.
2. Recognize relative energy involvement that fertilizers represent to production agriculture.
3. State the factors affecting the use of fertilizers which might inable a farmer to reduce his fertilizer needs.
4. List those practices of fertilizer application that will maximize fertilizer benefits.
5. State ways fertilizer applications can be combined with other cropping practices inorder to save energy.
6. Describe how the use of rotated legume crops will reduce fertilizer needs.
7. Respond correctly to the truth or falseness of statements regarding the manure nutrient values and soil benefit.
8. Describe the purpose for nitrification inhibitors and how they work.
9. Discuss how the wise use of herbicides can be both energy and economically efficient.
10. State at least four ways man might fight unwanted insect pests without resorting to excessive use of insecticides.

ENERGY AND AGRICULTURE

UNIT IV

SUGGESTED ACTIVITIES

Instructor:

1. Provide students with Objective Sheet
2. Provide students with Information and Assignment Sheets
3. Make Transparencies
4. Discuss Terminal and Specific Objectives
5. Discuss Information and Assignment Sheets
6. Give Test

Students:

1. Read Objectives
2. Study Information Sheets
3. Complete Assignment Sheets and turn in to instructor
4. Take Test

INSTRUCTIONAL MATERIALS

Included in this unit:

1. Objectives
2. Information Sheets
3. Transparency Masters

   TM 1 - ENERGY USED IN THE MANUFACTURE OF FERTILIZERS

   TM 2 - ENERGY COMSUMED BY U.S. AGRICULTURE

   TM 3 - CALIBRATE FERTILIZER DISTRIBUTION EQUIPMENT CAREFULLY - IT SAVES ENERGY

   TM 4 - SUGGESTED NITROGEN CREDITS FOR VARIOUS LEGUME CROPS

   TM 5 - PRODUCTION AND PLANT NUTRIENT CONTENT OF WET MANURE

INSTRUCTIONAL MATERIALS

TM 6 - ENERGY PER POUND OF ACTIVE INGREDIENT OF VARIOUS HERBICIDES

TM 7 - ENERGY RELATIONSHIPS IN WEED CONTROL IN SIX EXPERIMENTS ON CORN

4. Assignment Sheets

#1 - Comparing Composted Manure to Commercial Dry Fertilizer

#2 -

5. Test

6. Answers to Test

References:

1. Follett, Hunter, ENERGY FACTS: Proper Fertilizer Management Saves Energy. Cooperative Extension Service, Kansas State University, Manhattan, KS.

2. Vitosh, M.L., Fertilizer Management to Save Energy. Extension Bul. E-1136 ENERGY FACTS, Cooperative Extension Service, Michigan State University, E. Lansing, Michigan 48824.

3. Beach, Terry, Darrol Gray, Dennis Gray. Energy Uses in Nebraska Agriculture. Nebraska Energy Office, Box 95085, Lincoln, Neb. 68509.

ENERGY AND AGRICULTURE

UNIT IV

INFORMATION SHEET

I. Terms and Definitions

A. Banding - Placement of the fertilizer below and to either side of the crop seed

B. Broadcast - Uniformly sprinkling fertilizer on the surface of the entire crop field

C. Denitrification - The loss of or chemical change of nitrogen compounds rendering this nutrient unavailable for plant use

D. Fertilizer - Any material which supplies additional amounts of nutrients for plant growth

E. Herbicide - A chemical which destroys specific unwanted plant growth

F. Insecticide - A chemical which destroys specific unwanted insect crop pests

G. Nutrients - Essential elements in the soil which are necessary for plant growth. the main ones being nitrogen, phosphorus, and potassium

H. Permeability - The ease to which water freely moves down through the soil

I. Soil tilth - The ease to which the soil can be prepared for seed planting

II. Energy and Fertilizer

A. 40% of all energy used in production agriculure is for the manufacturing of fertilizer

B. Less than 1% of the total nations energy consumtion is used to manufacture fertilizer

C. 2/3 of energy used to make fertilizer is for nitrogen

D. BTU's used to make fertilizer (TM 1)

E. Ammonia is main ingrediant for making nitrogen fertilizers

F. One ton of ammonia requires 40,000 Cu. FT of natural gas of 40 million BTU's of energy

G. Proper fertilizer management could conserve 10% of fertilizer energy use (TM 2)

INFORMATION SHEET

III. Factors Affecting the Efficient Use of Fertilizers

A. Transportation represents 40% to 80% of fertilizer cost - use high analysis fertilizer to minimize costs and transportation energy

B. Soil fertility; testing will indicate necessary nutrients required for each crop

C. Crop reduction due to drougth, poor stand, insects, or disease results in less nutrient removal and can increase carry over of fertilizer to next year

D. Crop rotations, such as soybeans following a heavily fertilized corn crop may require little or no additional fertilization

E. Liming on acid soils releases available nutrients for plant needs increasing fertilizer efficiency and improves nodulation of legumes for increased nitrogen fixation

IV. Fertilizer Placement and Distribution

A. Banding or placing fertilizer near the seed is more efficient than broadcasting for row crops, and requires less fertilizer per acre

B. Uniform application is important for maximized yields; bulk blended fertilizers should be mixed well preventing segregation or separation of nutrients

C. Timely applications when most advantageous to crop saves nutrients from leaching or denitrification losses

D. Sidedressing may be justified for crops that require high levels of nitrogen late in growing period, particularily on shallow soils

E. Calibrate distribution equipment carefully (TM 3)

V. Combine Fertilization with Other Croppage Operations - Saves Energy

A. In conjuction with planting

B. Apply nitrogen, phosphorus and potassium in one bulk mix when possible; split fertilizer applications require more fuel

C. Supplimental nitrogen applied through the irrigation system will save energy

D. Sidedressing with nitrogen can be applied during cultivation at a time when crop growth needs it the most

INFORMATION SHEET

VI. Rotating Crops Grown Utilizing Nitrogen Fixing Legumes

A. Plowing under a good stand of alfalfa will supply 80 to 100 pounds of nitrogen per acre

B. A good stand of clover plowed under can supply 40 to 60 pounds of nitrogen per acre (TM 4)

VII. Manure Should Be Evaluated for Its Fertilizer Value

A. Manure should be analyzed to determine land application rates and nutient content

B. Manure nutrient composition varies by animal source

C. Manure increases soil tilth or aggregation, permeability and water holding ability, and organic content

D. Crop response is usually greater with manure than with an equivalent amount of man made fertilizer

VIII. Nitrification Inhibitors

A. Inhibitors to improve nitrogen fertilizer efficiency to the crop

B. Minimizes nitrogen losses (denitrification) when adverse soil and moisture conditions prevail (sandy or wet heavy soils)

C. Nitropyrin (N-serve), a Dow chemical, is a specific bactericide to kill nitrosomonas bacteria which are responsible for conversion of ammonia (NH_4^+) to nitrite (NO_2^-)

D. Is primarily used in liquid anhydros ammonia or nitrogen fertilizer solutions

IX. Herbicides; Proper Use Can Save Energy

A. Weed control with herbicides instead of tillage and cultivation reduces tractor fuel consumption

B. Herbicides do require fairly large amounts of energy to manufacture (TM 6)

C. Combining paraquat with already used herbicides may allow no-till cropping

D. Herbicides generally give greatest economic return of all weed control methods (TM 7)

INFORMATION SHEET

X. Insecticides

A. Losses from insect damage to crops - $4.0 billion annually

B. Insecticides require energy to manufacture, transport, and apply

C. Man's use of insecticides has created some environmental (pollution) problems and some insects have developed a resistance to certain chemicals (DDT) which now renders their use ineffective

D. Alternatives to using insecticides

1. Develop and/or use parasitic or predator insects or animals to destroy unwanted pest

2. Develop and/or use virus, fungus or bacteria that attack crop pests

3. Sterilize pest species using chemicals or radiation, preventing reproduction

4. Devlop and/or use plants resistant to destructive pests

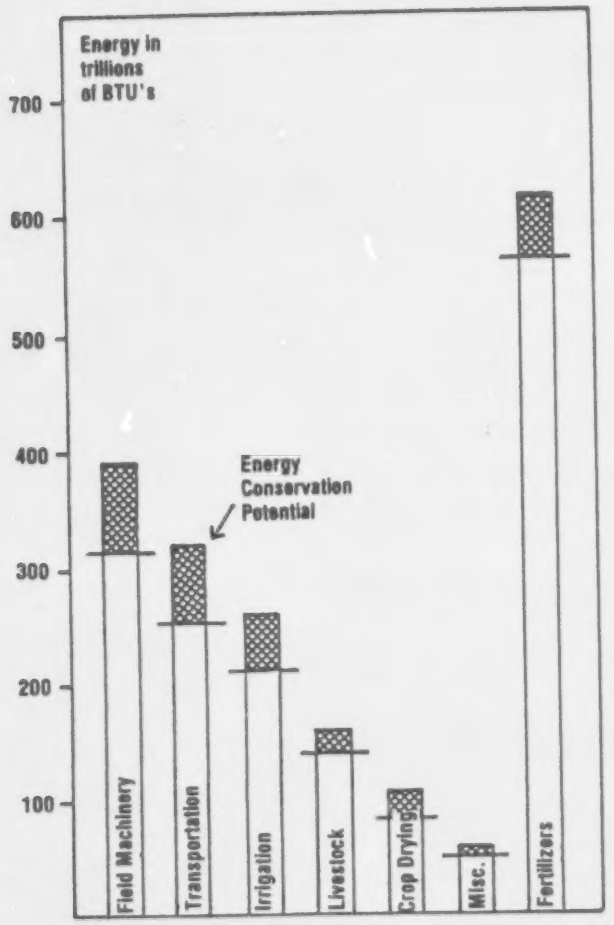
5. Use sanitation, tillage, crop rotation, land management, scheduled plantings, and other cultural practices to control pests

6. Support the use of laws and regulatory inforcement preventing the spread of pests

Energy Used In The Manufacture of Fertilizers

28,000 BTU's per pound Nitrogen (N)
equivalent to 1/5 gallon diesel Fuel
5,000 BTU's per pound Phosphorus (P_2O_5)
equivalent to 1/25 gallon diesel Fuel
4,000 BTU's per pound Potassium (K_2O)
equivalent to 1/30 gallon diesel Fuel

Typical fertilizer applications are equivalent to 30 gallons of diesel fuel per acre in energy used.



Energy consumed by U.S. Agriculture. Source: Energy and U.S. Agriculture, 1974 Data Base, developed by the Economic Research Service, U.S.D.A., Washington, D.C.

Calibrate Fertilizer Distribution Equipment Carefully - IT SAVES ENERGY

Example: Suppose a bulk spreader is set To apply Fertilizer at 300 LB per acre but upon calibration you find it actually delivered 350 LB per acre.

Point 1. IF Fertilizer cost $150/ton The excess Fertilizer cost you $4.00 per acre

Point 2. The 50 LBS of Excess Fertilizer represents approximetly 2-3 gal of diesel fuel of energy wasted per acre

Point 3. Excess fertilizer over and above maximum crop growth needs is costly and may even decrease yields

TM 3

Suggested Nitrogen Credits for Various Legume Crops.

Legume Crop	Nitrogen Credit-lb/A
Alfalfa—% Stand	
80-100%	120-140
50- 80%	40- 60
Less than 50%	0- 20
Second Year From Alfalfa—(Use 1/3 of First Year N Credit)	0- 50
Sweet Clover* —(Green Manure)	100-120
Red Clover*	40- 60
Legume Cash Crops	
Soybeans** —(Credit 1 lb N for each Bu Yield of Soybeans)	15- 50
Dry Beans	20- 30

* *Based on excellent stand and good management.*
** *For Wheat following soybeans, credit 1/2 lb N for each bu. yield of soybeans.*
Source: Crop and Soils Handbook, Kansas State University, January, 1975.

Table 3. Production and Plant Nutrient Content of Wet Manure*

Item	Dairy cattle	Beef cattle	Poultry	Swine	Sheep	Horse**
Production						
Animal size, lb.	1000	1000	5	100	100	——
Wet manure, tons/yr	11.86	10.95	0.046	1.46	0.73	7.50
Moisture (%)	85	85	72	82	77	59
			Pounds per Ton			
Nutrients						
Nitrogen (N)	10.0	14.0	25.0	10.0	28.0	14.0
Phosphorus (P)	5.0	4.0	11.0	2.8	4.2	5.0
Potassium (K)	8.0	9.0	10.0	7.6	20.0	15.0
Sulfur (S)	1.5	11.7	3.2	2.7	1.8	——
Calcium (Ca)	5.0	2.4	36.0	11.4	11.7	——
Iron (Fe)	0.1	0.1	2.3	0.6	0.3	——
Magnesium (Mg)	2.0	2.0	6.0	1.6	3.7	——
Boron (B)	0.01	0.01	0.01	0.09	——	——
Copper (Cu)	0.01	0.01	0.01	0.04	——	——
Manganese (Mn)	0.03	——	——	——	——	——
Zinc (Zn)	0.04	0.03	0.01	0.12	——	——

Data of Walsh and Hensler; University of Wisconsin, Extension Circular 550, June, 1971.
**Data from Handbook of Agronomy, VPI&SU Extension Bulletin 97, 1966.*

cropping opportunities. In terms of direct fuel use (excludes chemicals), reduced tillage can save up to 4 gal/acre and cut farm costs by 40%.

Using herbicides for weed control instead of tillage and cultivation can cut tractor fuel use because the tractor passes over the field fewer times. Herbicide production, however, requires large amounts of fossil fuel. Table 2 gives the energy content/unit of active ingredient of the most commonly used herbicides.

[redacted]: Energy per pound of active ingredient of various herbicides.

Herbicide	Btu/lb
Atrazine	133,200
Alachlor	170,500
2,4-D	87,300
Paraquat	178,300*
Lasso 15G	124,500

*Paraquat is equal to 44,580 Btu/pint

~~SOURCE: (5)~~

This chart, coupled with Fuel Requirements for Selected Farming Operations, Extension Bulletin E-780, will enable you to

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TM6

T. M. 6

[illegible] you to compare the energy for different farming practices. If you are already using herbicides for weed control, the switch to no-till may

acre as a moldboard plow. A spring or spike tooth harrow (drag) uses less fuel than a disc or field cultivator, and can often be used instead.

[illegible]. Energy relationships in weed control in six experiments on corn [illegible]*

Method of controlling weeds	Energy input for controlling weeds, kilocalories/acre	Yield of corn grain/acre		Net profit due to weed control, kilocalories/acre
		Bu	Kilocalories	
None	0	54	5,443,200	—
Cultivation	56,005	81	8,164,800	2,665,595
Herbicide	37,920	90	9,072,000	3,590,880
Hand labor	32,655	92	9,273,600	3,797,745

*The land was plowed, disked, and prepared for corn planting in the conventional manner.

[illegible]

[illegible] Economic relationships in weed control in six experiments on corn [illegible]

Method of controlling weeds	Costs/acre at 1976 prices			Yield of corn, bu/acre	Value of crop/acre at 1976 prices	Net profit/acre due to weed control
	Gasoline, machinery, chemicals	Labor	Total			
None	$ 0	$ 0	$ 0	54	$132.30	—
Cultivation	3.43	1.51		81	198.45	$61.23
Herbicide	9.58	0.31	9.71	90	220.50	78.49
Hand labor	0	159.00	159.00	92	225.40	-65.90

[illegible]

TM 7

TM 7

ENERGY AND AGRICULTURE

UNIT IV

ASSIGNMENT SHEET #1: Comparing Composted Manure to Commercial Dry Fertilizer

Procedure:

Part 1 - Take a shovelful of manure that has some bedding mixed with it and put into a pile between a few concrete blocks. Check the internal temperature daily, preferably twice daily. If the temperature gets over 68°C (154.4°F), mix the pile so that it is thoroughly exposed to air. When the pile no longer heats, the composting process is complete. (This takes a couple of months or so.)

Part 2 - Mix 1/3 soil, 1/3 sand, and 1/3 composted manure. Place in a cup, can, or clay pot. In another cup place a mixture of 1/2 soil and 1/2 sand and blend in a tablespoon of dry commercial fertilizer. In a third cup mix 1/2 soil and 1/2 sand. Plant several beet or radish seeds into each cup and water daily. Record your observations.

1. Which cup of seeds sprouted first?

2. Which cup seemed to produce the best growth of seeds?

3. What, if any, conclusions can you make from your observations?

ENERGY AND AGRICULTURE

UNIT IV

From TM 5 answer the following.

A. A man has 100 hogs which average 100 lbs. each.

1. How many tons of wet manure will these 100 hogs produce in one years time? _____

2. How many pounds of nitrogen is in this amount of manure? _____

3. How many pounds of phosphorus? _____

4. How many pounds of potassium? _____

B. Nutrient losses from this manure will vary depending on how it is stored, length of time stored, how it is applied to the land, and differences in climatic conditions. What would you have available to the plant in pounds if we spread 40 tons of hog manure per acre and you had the following losses; nitrogen - 50%, phosphorus - 10%, potassium - 10%.

Hint: Lbs. N, P, and K in 40 tons per acre before losses.

N= _____lbs., P= _____lbs., K= _____lbs. per acre

Lbs. N, P, and K per acre after losses.

N= _____lbs., P= _____lbs., K= _____lbs. per acre

C. Value of manure - Calculate commercial costs of N, P, and K.

1. If a 34% N (34-0-0) fertilizer cost $167 per ton, a pound of N cost $_____

2. If 46% P (0-46-0) fertilizer cost $166 per ton, a pound of P cost $_____

3. If 60% K (0-0-60) fertilizer cost $135 per ton, a pound of K cost $_____

ASSIGNMENT SHEET #2

Calculate value of manure.

1 ton of beef manure has:

_____lbs. of nitrogen per ton

_____lbs. of phosphorus per ton

_____lbs. of potassium per ton

Using the above dollar values for commercial fertilizer nutrients our beef manure is worth.

$\left(\frac{\$}{\text{LB. N}}\right)$ _____ X _____lbs. N in beef manure = $_____ value

$\left(\frac{\$}{\text{LB. P}}\right)$ _____ X _____lbs. P in beef manure = $_____ value

$\left(\frac{\$}{\text{LB. K}}\right)$ _____ X _____lbs. K in beef manure = $_____ value

ENERGY AND AGRICULTURE

UNIT IV

TEST

1. Match the definitions on the right with the correct term in the space provided.

_____a.	Fertilizer	1. Placement of the fertilizer below and to either side of the crop seed
_____b.	Denitrification	2. The ease to which water freely moves down through soil
_____c.	Broadcast	3. Uniformly sprinkling fertilizer on the surface of entire crop field
_____d.	Nutrients	4. The loss of, or chemical change in nitrogen compounds rendering this nutrient unavailable for plant use
_____e.	Herbicide	5. A chemical which destroys specific unwanted insect crop pests
_____f.	Permeability	6. Any material which supplies additional amounts of nutrients for plant growth
_____g.	Banding	7. A chemical which destroys specific unwanted plant growth
_____h.	Insecticide	8. Essential elements in the soil which are necessary for plant growth, the main ones being nitrogen, phosphorus, and potassium
_____i.	Soil tilth	9. The ease to which the soil can be prepared for seed planting

2. Circle the correct response.

   a. What percentage is fertilizer energy input as to compared to total farm production energy use.

      (a) 10% (b) 25% (c) 40% (d) 60%

   b. What percentage does energy inputs into fertilizer compare to our nation's total energy use?

      (a) 20% (b) 10% (c) 5% (d) less than 1%

TEST

2. c. 2/3 of all energy used to manufacture fertilizer is for making:
   (a) Boron (b) Potassium (c) Nitrogen (d) Phosphorus

   d. Nitrogen fertilizers primarily use:
   (a) Oil (b) Natural gas (c) Coal (d) Minerals
   in their manufacture.

   e. With better fertilizer management farmers could save as much as:
   (a) 10% (b) 25% (c) 33% of this energy input.

3. What factors should a farmer consider that will reduce his fertilizer needs?

   a.

   b.

   c.

   d.

   e.

4. List those practices in applying fertilizer which will help a farmer to maximize the fertilizer benefits to his crop.

   a.

   b.

   c.

   d.

   e.

5. In what ways can a farmer combine fertilizer application with other cropping practices to save energy? (Briefly state)

   a.

   b.

   c.

   d.

TEST

6. Describe how the use of rotated Legume crops will reduce fertilizer needs.

7. Indicate whether the following four statements regarding manure nutrient values and soil benefits are true or false. (Circle the correct answer)

   a. T F Manure should be analyzed to determine land application rates and nutrient content.

   b. T F The manure from various farm animals has the same nutrient values.

   c. T F Manure will decrease soil tilth and permeability and increase organic content and water holding ability.

   d. T F Crop response is usually greater with manure than with an equivalent amount of man made fertilizer.

8. Describe the purpose for nitrification inhibitors and how they work.

9. Discuss how the wise use of herbicides can be both energy and economically efficient.

10. State at least four ways man might fight unwanted insect pests without resorting to excessive use of insecticides.

ENERGY AND AGRICULTURE

UNIT IV

ANSWERS TO TEST

1. a. 6
   b. 4
   c. 3
   d. 8
   e. 7
   f. 2
   g. 1
   h. 5
   i. 9

2. The following should be circled:
   a. (c) 40%
   b. (d) less than 1%
   c. (c) Nitrogen
   d. (b) Natural gas
   e. (a) 10%

3. a. Use high analysis fertilizer to cut transportation and spreading costs.
   b. Soil testing - tailoring fertilizing to meet specific crop needs.
   c. Problems which result in very poor crop yields means less nutrients were removed from the soil and thus increases carryover reducing fertilizer needs for next crop.
   d. By rotating crops such as soybeans following a heavily fertilized corn crop may require little or no additional fertilization.
   e. Liming acid soils helps release bound up soil nutrients and increases legume modulation.

4. a. Band spreading of fertilizer is more efficient for row crops and requires less fertilizer per acre.
   b. Uniform or even spreading, well mixed loads for uniform consistency.
   c. Timely applications when it will do the crop the most good and prevents nutrients being lost to leaching and denitrification.
   d. Sidedressing certain crops that need high levels of N later in their growing season may actually save energy and materials in the long run.
   e. Calibrate fertilizer application equipment carefully-- spread or apply exact amounts to meet crop requirements.

ANSWERS TO TEST

5. a. Combine fertilization with planting.
   b. Combine fertilization with cultivation.
   c. Apply N, P, and K in one blended bulk mix rather than split applications.
   d. Use irrigation system to apply supplimental nitrogen.

6. Legumes have nitrogen fixing bacteria in their nodules which fix atmospheric N, thus when nitrogen rich roots and nodules of these plants are plowed in they release nitrogen for other crops. This will reduce the amount of N fertilizer needed.

7. a. T c. F
   b. F d. T

8. Nitrification inhibitors improve the efficiency rates of available nitrogen for crop uptake by minimizing nitrogen losses. This material accomplishes this by killing nitrosomonas bacteria responsible for conversion of amonia to unavailable nitrates.

9. With proper use herbicides can reduce tillage and cultivation requirements, in some cases may allow no till cropping. This saves energy and nets increased profits. Eliminating unwanted weeds also increases crop yields which results in greatest economic return to the farmer.

10. a. Using parasitic or predator insects to destroy unwanted crop pests.
    b. Using fungus, virus, or bacteria which attack and kill pests.
    c. Sterilize the pest, preventing their reproduction.
    d. Use crop plants resistant to pests.
    e. Use crop cultivating practices such as sanitation, tillage, crop rotations, land management, and scheduled plantings to control pests.
    f. Support regulatory laws and inforcements by agricultural agencies which are fighting the spread of crop pests and diseases.

ENERGY AND AGRICULTURE

UNIT V

GRAIN PRODUCTION, HARVESTING, HANDLING AND STORAGE PRACTICES THAT SAVE ENERGY

TERMINAL OBJECTIVE

Upon completion of this unit, students will be able to identify terms and describe energy saving management decisions and practices involved in farm produced grain, the energy saving factors for tillage, planting grain moistures at harvest, grain drying, grain storage, and grain utilization. This objective will be considered achieved by scoring at least eighty-five percent on the test.

SPECIFIC OBJECTIVES

After completion of this unit, students will be able to:

1. Match terms associated with grain production, harvesting, handling, and storage energy saving practices with their correct definitions.
2. Describe five of the seven ways tillage practices can be made more energy efficient.
3. State three factors used in selecting seed variety and planting dates.
4. Describe three reasons why care and adjustment of harvesting equipment is economical and energy efficient.
5. Recognize the truth or falseness regarding statements about grain moistures at harvest.
6. Recognize the factuality of statements regarding energy saving grain drying practices.
7. Indicate the truth or falseness of statements about high temperature drying systems.
8. Identify the correct word which makes batch or continuous flow dryer energy comsumption statements true.
9. List six of the nine good grain management practices a farmer can do to save energy.
10. Describe ways energy saving decisions might be arrived at regarding grain storage and amount of drying if livestock production is involved.

ENERGY AND AGRICULTURE

UNIT V

SUGGESTED ACTIVITIES

Instructor:

1. Provide students with Objective Sheet
2. Provide students with Information and Assignment Sheets
3. Make Transparencies
4. Disucss Terminal and Specific Objectives
5. Discuss Information and Assignment Sheets
6. Give Test

Students:

1. Read Objectives
2. Study Information Sheets
3. Complete Assignment Sheet and turn in to instructor
4. Take Test

INSTRUCTIONAL MATERIALS

Included in this unit:

1. Objectives
2. Information Sheets
3. Transparency Masters

TM 1 - AMOUNT OF MOISTURE REMOVED AND APPROXIMATE NUMBER OF BTU'S REQUIRED PER BUSHEL TO DRY CORN

TM 2 - ESTIMATED ENERGY REQUIREMENTS FOR LOW-TEMPERATURE CORN DRYING and EFFECTS OF AUXILIARY HEAT ON LOW-TEMPERATURE DRYING

TM 3 - ENERGY EFFICIENCIES OF VARIOUS DRYING TECHNIQUES

TM 4 - HEAT ENERGY REQUIREMENTS FOR BATCH OR CONTINUOUS-FLOW DRYERS AT VARIOUS DRYING TEMPERATURES AND AIRFLOWS

INSTRUCTIONAL MATERIALS

TM 5 - CONVENTIONAL BATCH OR CONTINUOUS-FLOW DRYING VS. DRYERATION

TM 6 - CONVENTIONAL BATCH OR CONTINUOUS-FLOW DRYING VS. COMBINATION

4. Assignment Sheet

   #1 - Energy Required for Grain Drying

5. Answers to Assignment Sheet

6. Test

7. Answers to Test

References:

1. Rose, William T., Bill Stout, Claudia Myers, Energy Management for Field Crop Production. Extension Bul. E-1407 ENERGY FACTS, Cooperative Extension Service, Michigan State University, E. Lansing, Michigan 48824.

2. Maddex, Robert L. and Fred W. Bakker-Arkema, Reducing Energy Requirements for Harvesting, Drying and Storing Grain. Extension Bul. E-1168 ENERGY FACTS, Cooperative Extension Service, Michigan State University, E. Lansing, Michigan 48824.

3. Holmes, Elwyn S., AG FACTS: Energy Management in Grain Drying. Cooperative Extension Service, Kansas State University, Manhattan, KS.

4. Holmes, Elwyn S., Energy Efficiency in Kansas Agriculture: Saving Fuel in Grain Drying. Cooperative Extension Service, Kansas State University, Manhattan, KS.

5. Holmes, Elwyn and Dennis Kuhlman, ENERGY FACTS: Guide to Low Temperature and Air Drying Grain. Cooperative Extension Service, Kansas State University, Manhattan, KS.

ENERGY AND AGRICULTURE

UNIT V

INFORMATION SHEET

I. Terms and Definitions

A. Drying points - The difference between percent moisture content at harvest and desired percent moisture for storage, example: 25% at harvest to 15% storage = 10 points

B. Low temperature drying - An in-bin drying method where moisture is removed over many days (20-30 days) using low volume flow of slightly heated air (1-5 CFM/BU and 3-5°F rise)

C. Percent moisture - The amount of water retained in a kernel of grain expressed as a percent of its total weight

D. Natural air drying - Outside air is not heated, other than 1-2°F that the fan motor provides, and is passed through grain with same volume of flow as low termperature drying

E. High temperature drying - A high air flow of 40-80 CFM/BU is heated to high temperatures of 130°-230°F which is used to remove grain moisture

F. Batch drying - Wet grain is dried and cooled in successive steps and then removed to storage

G. Continuous-flow drying - Wet grain enters the dryer, is dried, then cooled in a continuous process

H. CFM/BU - A required volume of air to dry each bushel of grain given in terms of cubic feet a minute per bushel

I. Dryeration - Process uses heat retained in the grain from high temperature drying to affect further moisture reduction, process involves holding hot grain in a steeping bin for a 6-8 hr. tempering period with no air flow, then using a low air flow ½ CFM for cooling 8-12 hrs. removing 2 drying points from grain

II. Tillage

A. Consider reduced tillage

1. Benefits are: erosion reduction, less soil compaction, improved weed control, increased soil moisture storage, reduced labor, expenses and more double cropping possibility

2. Reduced tillage may save up to 4 gal/acre and cut farm costs by 40%

INFORMATION SHEET

B. Don't till too deep

1. The greater the depth of tillage the more fuel used per acre

a. Plowing or chiseling of soybeans, dry beans, wheat or corn can be done at shallow depths of 5-7"

2. Secondary tillage of discing or dragging should be done at ½ the depth of plowing

a. brings less weed seeds to soil surface

b. Saves subsoil moisture

c. Saves additional fuel

C. Use most energy efficient implement

1. Chisel plow uses ½ the fuel as moldboard plow

2. Spring or spike tooth harrows use less fuel than disc or field cullivator

D. Combine tillage operations with other field operations

1. Reduces fuel and labor time

2. Examples: pulling spring tooth harrow behind a disc, herbicide application combined with planter operation

E. Do not till wet fields

1. Increases soil compaction

2. Increases draft and fuel requirements

F. Don't create deep dead furrows

1. They require additional tillage to cover

2. In a 40 acre field, two extra passes to cover the dead furrow uses 5 gal. of extra fuel

G. Operate wisely, adjust and maintain implements

1. Gear up - throttle back practice

2. Keep wheel slippage between 10-15%

INFORMATION SHEET

3. Adjust and use proper tillage tool for soil conditions

4. Analyze fields for optimum work patterns

5. Rebuild or replace worn parts, keep implement bright and new as possible for optimum field efficiency

6. Operate implement at correct ground speed

III. Hybrid Seed and Planting Date Selection

A. Selecting early or medium maturity corn can reduce harvest grain moisture by several percentage points

B. Use guides which compare yields to harvest moistures of different hybrid varieties

C. Plant as early as possible so harvest occurs at optimum climate condition (drying harvest season)

IV. Care of Equipment for Efficient Harvest

A. Adjust combine frequently, reduces broken corn kernels and trash with corn, and maximizes yields

B. Clean corn or grain dries best with least amount of energy

C. Maintain equipment for maximum field efficiency and least fuel consumption, adjust according to:

1. Every half day during early part of harvest

2. Changes in fields

3. Different grain varieties

V. Grain Moistures at Harvest

A. Twice as much moisture (LBS) must be removed when drying corn at 27% to 15½% as compared to 22% to 15½% moisture

B. Harvest grain below 30% moisture, harvesting above 30% results in greater kernel damage reducing corn quality

C. It takes 24% less energy to dry corn from 26% to 16% moisture than it does from 30% to 16%

D. Optimum moisture conditions for combining

INFORMATION SHEET

1. Corn at 25% moisture

2. Grain sorghum at 22%

3. Soybeans at 18%

E. Weather, weeds and drop pests may dictate when harvest actually occurs

VI. Grain Drying Practices That Save Energy

A. Low-temperature drying using slightly heated air (3-5° rise) over an extended period of time (TM 2)

B. Dryeration processed grain should be removed from steeping bins and placed to cool in storage bin, further drying can be achieved here using unheated low volume airflow (½-1 CFM/BU)

C. Use natural-air drying when applicable

1. The fan motor provides some heat (1-2°F) and the low volume of air saves energy but takes upwards of 20-30 days to dry grain

2. Air humidity should be under 65% and weather conditions favorable when using natural air drying

3. Keep grain depths under 16 feet

D. Do not overdry grain below 13% moisture

E. Solar collector used to preheat dryer air can significantly reduce fuel requirements

VII. High Temperature-Rapid Grain Drying Practices

A. Continuous-flow drying and batch drying systems are fast but inefficient in use of energy

B. Only 40-50% of all the heat energy produced is actually used to remove grain moisture

C. These dryers heat a high volume of fast moving air to 130°-230°F which passes rapidly through the grain and does not have enough contact time to extract all the moisture it is capable of carrying

VIII. Reducing Energy Consumption in Batch or Continuous-flow Dryers (TM 3)

A. Increasing temperature of heated air with a corresponding decrease in airflow is energy efficient (TM 4)

INFORMATION SHEET

B. Increasing air temperature and deeping airflow the same will increase energy drying efficiency (TM 3)

C. Continuous-flow dryers which recirculate cooling air and a portion of the drying air to recover and recycle exhaust heat can save 15-20% drying energy

D. Consider dryeration grain drying (TM 5)

1. Can save 20% energy over straight high temperature drying

2. Increases effective capacity of batch or continuous-flow drying system

E. Combination of high temperature and low temperature drying methods, savings of 50% may be realized (TM 6)

IX. Good Management Saves Energy

A. Clean grain free of trash and fines does not stop airflow during drying

B. Clean out air tunnels perforated floors to allow maxiumu airflow

C. Open all roof vents and hatches to allow free release of moisture

D. Keep grain level in drying bins

E. After drying close all roof hatches and fan openings to prevent moisture re-entry

F. Size drier for volume of grain to be handled

G. Set drying temperature at recommended level for the grain being dried

H. Follow drier manufacture's instructions for control settings and maintainence

I. Inspect grain regularly for quality, temperature and moisture in dryer and in storage

X. Dry Grain to Meet Storage and Utilization Needs and Save Additional Energy

A. Feed out higher moisture corn through winter months

1. Ruminant animals do well on higher moisture grain

B. Consider air tight storage for holding high moisture corn when harvested under adverse conditions

C. Propionic acid allows preservation of high moisture corn without fermentation for cattle feed

U5

– Amount of moisture removed and approximate number of BTUs required per bushel to dry corn.

Initial moisture content	Final moisture content							
	12%		14%		16%		18%	
%	Lbs. water	BTU*	Lbs. water	BTU	Lbs. water	BTU	Lbs. water	BTU
30	14.40	33,120	12.80	29,440	11.2	25,760	9.8	22,540
28	12.44	28,610	10.89	25,040	9.4	21,620	8.0	18,400
26	10.59	24,350	9.08	20,810	7.6	17,480	6.2	14,260
24	8.84	20,330	7.37	16,950	5.9	13,570	4.5	10,350
22	7.18	16,514	5.74	13,200	4.3	9,890	2.7	6,210
20	5.60	12,880	4.20	9,660	2.8	6,440	1.4	3,220
18	4.10	9,430	2.73	6,280	1.4	3,220		
16	2.32	5,336	.99	2,270				

*A range of 1,500 to 3,000 BTUs may be required to evaporate a pound of water. 2,300 BTU/lb was used for these calculations.

TM-1

Estimated Energy Requirements for Low-Temperature Corn Drying 1/2/

Initial Moisture (percent)	Required Airflow 3/ (cfm)	Corn depth 8'	12'	16'	20'
		(KWH/Bu)			
20	1.0	0.84	1.00	1.26	1.64
23	1.5	1.41	1.85	2.59	3.64
24	2.0	1.74	2.50	3.75	5.57
25	2.5	2.13	3.31	5.24	8.04
26	3.0	2.58	4.29	7.08	11.12

1/Corn dried to equilibrium moisture content with 3°F temperature rise provided by electrical resistance heating plus an additional 2°F provided by the fan.

2/Fan efficiency assumed to be 50 percent and motor efficiency 85 percent.

3/Airflow required to safely dry corn before spoilage occurs.

TABLE 4. Effects of Auxiliary Heat on Low-Temperature Drying 1/

Electric Heat added 2/ (°F)	Results: Final moisture (percent)	Drying time (days)	Energy use (KWH/Bu)
0	15.2	37	2.0
1	14.7	34	2.4
3	13.7	29	3.0
5	12.9	26	3.4
7	12.2	22	3.7

1/ For a 16-ft. depth of 24 percent moisture corn with 2 cfm/bu airflow.

2/ 2°F temperature rise assumed added by fan.

ENERGY EFFICIENCIES OF VARIOUS DRYING TECHNIQUES

Drying technique	Drying efficiency* (bu/gal of LP gas)	Comments
1. Batch or continuous flow with cooling in dryer (180F to 220F).	6.5	High capacity, flexible, high kernel stress from fast drying and cooling, incomplete air saturation.
2. Batch or continuous flow with dryeration† (180F to 220F).	8.1	Increased capital investment, two handlings to storage, 50 to 60% increase in throughput, improved product quality.
3. Bin drying without stirring device (10F rise with 55% relative humidity humidistat control.	9.2	Overdrying in bottom layers, difficult to manage for optimum performance.
4. Bin drying with stirring device (110F to 140F).	9.2	Mechanical reliability may be a problem, flexible in grain depth, fast batch procedures.
5. Bin batch-drying cooling in bin (120F to 140F).	9.2	Modest price, medium capacity, additional manual labor for daily leveling and unloading.
6. Electric bin drying‡ (2F to 7F rise).	7.7	Slow drying rate, increased threat of mold, good grain quality, limits on grain moisture content.
7. Combination system, 5% with batch or continuous-flow drying, 2% with dryeration, 3% with aeration.§	12.6	Same as technique 1 or 5, except final drying (without heat) and cooling done in another bin; increase in potential for mold during final drying.
8. Drying with ambient air (2F rise).	---	Slow drying, grain must be below 20% in moisture content, vulnerable to mold, weather conditions critical.
9. Solar heat drying	---	Still in the developmental stage; use as a supplemental source of heat may become practical with new technology.

*Based on drying 10 points (25% to 15% wb), 2100 Btu per lb of water for high-temperature dryer, and 1500 Btu per lb of water for bin drying systems.
†Dryeration response is a constant 2 points of drying, assuming a kernel temperature of 120 to 140 F.
‡Electric drying based on 0.35 kw-hr per bu per point of moisture removed.
§Based on dryeration airflow of 1 cu ft per bu per min for 20 hr plus aeration airflow of 0.5 cu ft per bu per min for 30 days.

From Agricultural Engineering, May 1975

TM3

Heat Energy Requirements for Batch or Continuous-Flow Dryers at Various Drying Temperatures and Airflows 1/ 2/

Drying Air Temperature °F	Airflow (cfm/bu) 40	50	60	70	80
	Heat Energy Required (BTU/Bu)				
130	18,800	21,000	23,000	25,500	27,800
165	17,200	19,100	21,000	23,000	25,200
200	15,300	16,900	18,500	19,800	21,100
235	14,000	15,300	16,300	17,200	18,200

1/ Heat energy to dry corn from 25 to 15 percent moisture.
2/ Ambient conditions of 50°F and 75 percent relative humidity.

. Conventional Batch or Continuous Flow-Drying vs. Dryeration

Method	Moisture Content (percent)	Heat Energy (BTU/bu)	Electrical Energy (KWH/bu)	Total BTU Equivalent
Conventional	25-15	18,500	.035	18,620
Dryeration	25-17	14,700	.021	14,830
	17-15	------	.016	

Conventional Batch or Continuous-Flow Drying Vs. Combination Drying

Method	Moisture Content (percent)	Heat Energy (BTU/bu)	Electrical Energy (KWH/bu)	Total BTU Equivalent
Conventional	25-15	18,500	.035	18,620
Combination Drying	25-20	9,300	.014	14,120
	20-15	------	1.400	

ENERGY AND AGRICULTURE

UNIT V

ASSIGNMENT SHEET #1: Energy Required for Grain Drying

Based on the information given calculate the following grain drying requirements. Use of TM 2 and TM 4 is necessary.

A farmer harvests 20,000 bushels of corn at 25% moisture content. He will want to dry it to equilibrium moisture content (safe storage moisture of 13%).

1. How much energy (total BTU's) will be required to dry this grain using a low-temperature system? (corn depth is 12') (Use TM 2)

   Hint: a KWH = 3,412 BTU's

2. How much energy (total BTU's) will be required to dry this grain using a batch or continuous-flow dryer? (High temperature drying) He will use 200°F drying air with a 60 CFM/BU airflow to dry to 15% and dryeration process will bring the corn down to 13%. Calculate only the high temperature drying energy requirements. (Use TM 4)

3. What is the difference in BTU's of energy between these two systems?

ENERGY AND AGRICULTURE

UNIT V

ANSWERS TO ASSIGNMENT SHEET

1. $20{,}000 \text{ BU} \times \frac{3.3 \text{ KWH}}{\text{BU}} \times \frac{3{,}412 \text{ BTU's}}{\text{KWH}} = 225{,}874{,}400 \text{ BTU's}$

2. 20,000 BU x 18,500 BTU/BU = 370,000,000 BTU's

3. Difference is 370,000,000 BTU's
   225,874,400 BTU's
   144,125,600 BTU's

ENERGY AND AGRICULTURE

UNIT V

TEST

1. Match the definitions on the right with the correct term in the space provided.

_____a. Batch drying

_____b. Dryeration

_____c. CFM/BU

_____d. Continuous-flow drying

_____e. Drying points

_____f. Low-temperature drying

_____g. High-temperature drying

_____h. Natural air drying

_____i. Percent moisture

1. Difference between percent moisture of grain at harvest and desired percent moisture for storage
2. The in-bin drying method using low volume flow of slightly heated air over a period of many days
3. The amount of water retained in a kernel of grain expressed as a percent of its total weight
4. Outside air is not heated yet is used to dry grain with low volume of airflow
5. A highly heated, high volume of airflow is used to remove grain moisture
6. Wet grain enters the dryer, is dried, then cooled in a continuous process
7. A required volume of air to dry each bushel of grain in a given minute of time
8. Wet grain is dried and cooled in successive steps and than removed to storage
9. Utilizes heat retained in the grain from high temperature drying to affect further moisture reduction

2. Describe five of the seven ways tillage practices can be made more energy efficient.

a.

b.

c.

d.

TEST

2. e.

BONUS f.

BONUS g.

3. State three factors used in selecting seed variety and planting dates.

   a.

   c.

4. Describe three reasons why care and adjustment of harvesting equipment is economical and energy efficient.

   a.

   b.

   c.

5. Recognize the truth or falseness of the following statements regarding grain moistures at harvest. (Circle the correct answer)

   a. T F Twice as much moisture must be removed when drying corn at 27% to 15½% as compared to drying 22% to 15½% moisture.

   b. T F Harvesting above 30% moisture results in greater kernel damage and reduction of grain quality.

   c. T F It takes 24% less energy to dry corn from 26% to 16% than 30% to 26%.

   d. T F The optimum moisture conditions for combining corn is at 29% moisture.

   e. T F Weather weeds and crop pests may dictate when harvest actually occurs.

6. Place an X next to the statement which is NOT a grain drying practice that saves energy.

   _____a. Low temperature drying over a longer period of time as compared to high temperature drying.

   _____b. Incorporating the dryeration process if high temperature drying method is used to dry grain.

TEST

6. cont.

_____c. Use natural-air drying method when time permits and air humidity is low.

_____d. Do not over dry grain below 16½% moisture.

_____e. Solar collectors used to preheat dryer air can significantly reduce fuel requirements and are proven to be cost efficient.

7. Indicate the truth or falseness of the following statements about high temperature drying systems. (Circle the correct answer)

a. T F Continuous-flow and batch drying systems are fast but inefficient to use of energy.

b. T F Some 70-80% of all heat energy produced is used efficiently to remove grain moisture.

c. T F The very hot and large amount of fast moving air does not have enough contact time to extract all the moisture from grain it is capable of carrying.

8. Circle the correct word so that the statement reads correctly about reducing energy consumption in batch or continuous-flow dryers.

a. (Increasing) (Decreasing) temperature of heated air with a corresponding (increase) (decrease) in airflow will save energy.

b. (Increasing) (Decreasing) air temperature and keeping airflow the same will (increase) (decrease) drying efficiency.

c. Continuous-flow dryers which recirculate cooling air and a portion of the drying air to recover and recycle exhaust heat can save as much as (5-7%) (15-20%) (25-30%) (40-50%) drying energy.

d. Dryeration processed grain can save (10%) (20%) (30%) (40%) energy over straight high temperature drying, and it will (increase) (decrease) effective grain drying capacity.

e. Combining high temperature and low terperature drying methods, savings of (10%) (25%) (50%) (75%) may be realized.

9. List six out of the nine good grain management practices which you as a grain farmer can do that will help save energy.

a.

b.

c.

d.

TEST

9. e.

f.

BONUS g.

BONUS h.

BONUS i.

10. If knowing that some or all of the grain produced is going to be used as livestock feed and what storage facilities exsist, what energy saving decisions could that farmer make regarding his grain utilization.

ENERGY AND AGRICULTURE

UNIT V

ANSWERS TO TEST

1. a. 8
   b. 9
   c. 7
   d. 6
   e. 1
   f. 2
   g. 5
   h. 4
   i. 3

2. a. Reducing amount of tillage
   b. Shallow tillage
   c. Use most energy efficient implement
   d. Combine tillage and other field operations
   e. Don't till wet fields
   f. Don't create deep dead furrows
   g. Operate wisely, adjust and maintain implements

3. a. Select early or medium maturing corn hybrids to reduce harvest grain moisture
   b. Use hybrid variety guides which compare yields to harvest moistures
   c. Plant early so harvest occurs during drying harvest season

4. a. Adjusting the combine frequently reduces broken corn dernels and trash, and maximizes the yield
   b. Clean corn or grain dries best with least amount of energy
   c. Maintain equipment for maximum field efficiency and least fuel consumption

5. a. T
   b. T
   c. F
   d. F
   e. T

6. The following should have an X
   d.
   e.

7. a. T
   b. F
   c. T

ANSWERS TO TEST

8. a. increase, decrease
   b. increase, increase
   c. 15-20%
   d. 20%, increase
   e. 50%

9. a. Clean grain free of trash and fines for unhindered drying airflow
   b. Clean air tunnels and perforated floors to allow free airflow
   c. Open all roof vents and hatches during drying
   d. Level grain in drying bins
   e. Close all roof vents, hatches, and fan openings after drying has been completed
   f. Size the dryer for amount of grain to be handled
   g. Set drying temperatures at recommended levels
   h. Follow manufacturer's instructions for control settings and maintainence
   i. Inspect grain regularly for quality, temperature, and moisture in dryers and in storage

10. He may opt to feed out his higher moisture corn through the cold winter months as higher moisture corn can be stored safely under cold conditions. Cattle do very well on higher moisture but well preserved grain. Use of propionic acid will also preserve high moisture corn without having to ferment it. Storing and using this grain at higher moisture contents saves the energy required to dry it to safe moisture contents for storage during warm summer months.

    The farmer may wish to consider adapting or building air tight grain storage for handling high moisture corn harvested under adverse conditions. This would prevent grain loss to spoilage and save drying energy.